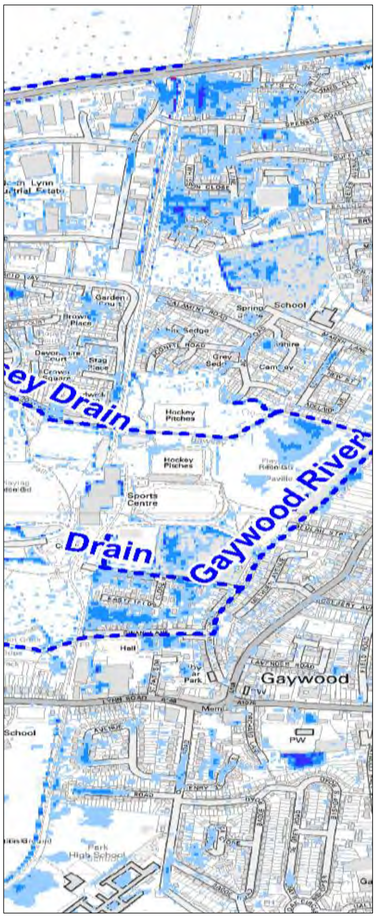
CAPITA SYMONDS

King's Lynn and West Norfolk Settlements Surface Water Management Plan



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RELATED DOCUMENTS

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Executive Summary

This document forms a Surface Water Management Plan (SWMP) for selected settlements within the Borough Council of King's Lynn and West Norfolk. The SWMP has been undertaken following a four phase approach based on the methodology set out in Defra's SWMP Technical Guidance document, published in March 2010. These four phases comprise of: Phase 1 – Preparation; Phase 2 – Risk Assessment; Phase 3 – Options; and Phase 4 – Implementation and Review. This document covers Phases 2, 3 and 4 of this process and should be read in conjunction with the Phase 1 report, which was completed by Mott MacDonald in November 2010.

Phase 1: Preparation

Phase 1 of the SWMP focussed on preparing and scoping the requirements of the study. Key outcomes of this phase of work included; the collection and review of surface water data from relevant stakeholders, developing partnerships between risk management organisations responsible for local flood risk management, and determining how these stakeholders will be engaged throughout the duration of the study. This phase was completed on behalf of the Borough Council in November 2010.

Phase 2: Risk Assessment

As part of Phase 2, a site inspection of 17 settlements has been undertaken to determine the risk of surface water flooding, and to identify those which would benefit from surface water modelling. Table i identifies the recommendations based on these site inspections.

Table i. Summary of Site Inspection Recommendations

Modelling recommended	Review of drainage infrastructure	Minimal risk – maintain existing maintenance regime
Kings Lynn	Feltwell	East Rudham
Downham Market	Hunstanton	Wimbotsham
Heacham	Burnham Market	Southery
Snettisham	Shouldham	South Creake
	Dersingham	Terrington St Clement
	Gayton	
	West Rudham	
	North Creake	

Direct rainfall modelling has been undertaken across King's Lynn, Downham Market, Heacham and Snettisham for a range of return periods to identify areas where surface water flooding is likely to occur during specified rainfall events. An assessment of flood risk from other local sources, including sewer flooding, groundwater flooding and flooding from ordinary watercourses, has also been undertaken as part of this phase of work. The predicted consequences of flooding to property, businesses and infrastructure has been analysed and those areas identified to be at more significant risk have been identified as Local Flood Risk Zones (LFRZ). From these LFRZs, and future reporting on flooding risk, the Council (at a later date) may wish to identify Critical Drainage Areas (CDAs) based on the criteria specified within this report.

It is recommended that a more detailed assessment of larger ordinary watercourses (e.g. King's Lynn - Gaywood River, Middleton Stop Drain etc.) is undertaken to assist in understanding the risk from these sources. These models can then be coupled with the pluvial model (created for this SWMP) to replace the bank full conditions assumed in the model. It should be noted that this assessment is broad scale and does not provide a detailed analysis of groundwater; it only aims to provide an indication of where more detailed consideration of the risks may be required.

The causes of groundwater flooding are generally understood. However, groundwater flooding is dependent on local variations in topography, geology and soils. It is difficult to predict the actual location, timing and extent of groundwater flooding without comprehensive datasets.

Analysis of the number of properties and infrastructure at risk of flooding has been undertaken for the rainfall event with a 1 in 100 probability of occurring in any given year (1% Annual Exceedance Probability [AEP]). A review of the results indicate that 594 residential properties in the modelled settlements, could be at risk of surface water flooding of depths greater than 0.1m (above an assumed 0.1m building threshold) during a 100 year probability (1% AEP) rainfall event – the modelled results also indicate that approximately 900 properties (including commercial, infrastructure and residential) are at risk of flood depth of 0.1m. Table ii, overleaf, identifies the approximate number of flooded buildings within the modelled settlements.

Table ii. Flooded Properties Summary – Depths Greater Than 10cm

Property Type	Flood Risk Vulnerability Classification	Model				100yr Totals
		Downham Market	Heacham	Kings Lynn	Snettisham	
Infrastructure	Essential Infrastructure	2	0	1	0	3
	Highly Vulnerable	0	0	1	0	1
	More Vulnerable	2	0	2	1	5
	Sub-total	**2**	**0**	**3**	**1**	**6**
Households	Non-Deprived (All)	71	30	324	21	446
	Non-Deprived (Basements Only)	0	0	0	0	0
	Deprived (All)	0	0	148	0	148
	Deprived (Basements Only)	0	0	0	0	0
	Sub-total	**71**	**30**	**472**	**21**	**594**
Commercial / Industrial	Units (All)	12	0	45	1	58
	Units (Basements Only)	0	0	0	0	0

Phase 3: Options Assessment

Due to the dispersed nature of the surface water flooding results, Critical Drainage Areas (CDAs) were difficult to establish for the modelled settlements. Therefore, it was agreed with the steering group, that Local Flood Risk Zones (LFRZs) would be identified within this SWMP and not CDAs. These LFRZs could be investigated at a later stage based on updated information or recording of new flood events to determine if the actual risk warrants a reclassification as a CDA. No specific options have been defined for these LFRZs but throughout the study area there are opportunities for generic measures to be implemented. This could be through the establishment of a policy position on issues including the widespread use of water conservation measures such as water butts and rainwater harvesting technology, use of soakaways, permeable paving and green roofs and a tougher position on development requirements. In addition, there are opportunities to raise community awareness to surface water flood risk across the whole study area. These measures and options have been discussed in this report.

In addition to these options/measures, it is recommended that Norfolk County Council develops an integrated, risk-based, decision-support framework to support tactical (real-time) flood incident management that includes the King's Lynn and West Norfolk area. This will help to facilitate the deployment of Council operational resources to key areas of greatest risk during a flood event. In conjunction, it is recommended that additional rainfall gauging stations be considered for installation to assist with the Council's responsibility to investigate flood incidents as required under the FWMA 2010.

Phase 4: Implementation & Review

Phase 4 establishes a long-term Action Plan for Norfolk County Council and Borough Council of King's Lynn and West Norfolk, to assist in its role under the FWMA to lead in the management of surface water, groundwater and ordinary watercourse flood risk across the study area. The purpose of the Action Plan is to:

- Outline the actions required to implement any preferred options identified in Phase 3;
- Identify the partners or stakeholders responsible for implementing the action;
- Provide an indication of the priority of the actions and a timescale for delivery; and
- Outline actions required to meet the requirements for Norfolk County Council as Lead Local Flood Authority under the Flood and Water Management Act 2010.

As part of the preparation of the Action Plan, the requirement for a Strategic Environmental Assessment (SEA), an Appropriate Assessment (required by the Habitats Directive) or an Article 4.7 assessment (under the Water Framework Directive) was considered and a 'screening decision', based on a number of factors, was made which suggested that the SWMP alone does not currently require any of these assessments. However, due consideration has been given to the Dersingham Bog which is considered a Special Area of Conservation. As such, a requirement for monitoring this area is included within the Action Plan to ensure detrimental impacts to the bog are identified and rectified/managed in a timely manner.

Glossary

Term	Definition
Aquifer	A source of groundwater comprising water bearing rock, sand or gravel capable of yielding significant quantities of water.
AMP	Asset Management Plan, see below
Anglian Water	The Water Authority for this area.
Asset Management Plan	A plan for managing water and sewerage company (WaSC) infrastructure and other assets in order to deliver an agreed standard of service.
AStGWF	Areas Susceptible to GroundWater Flooding. A national data set held by the Environment Agency identifying the risk of groundwater emergence within an area.
AStSWF	Areas Susceptible to Surface Water Flooding. A national data set held by the Environment Agency and based on high level modelling which shows areas potentially at risk of surface water flooding.
Bank Full	The flow stage of a watercourse in which the stream completely fills its channel and the elevation of the water surface coincides with the top of the watercourses banks.
Catchment Flood Management Plan (CFMP)	A high-level planning strategy through which the Environment Agency works with their key decision makers within a river catchment to identify and agree policies to secure the long-term sustainable management of flood risk.
CDA	Critical Drainage Area, see below.
Critical Drainage Area	A discrete geographic area (usually a hydrological catchment) where multiple and interlinked sources of flood risk (surface water, groundwater, sewer, main river and/or tidal) cause flooding in one or more Local Flood Risk Zones during severe weather thereby affecting people, property or local infrastructure.
CFMP	Catchment Flood Management Plan, see entry above
CIRIA	Construction Industry Research and Information Association
Civil Contingencies Act	This UK Parliamentary Act delivers a single framework for civil protection in the UK. As part of the Act, Local Resilience Forums have a duty to put into place emergency plans for a range of circumstances including flooding.
CLG	Government Department for Communities and Local Government
Climate Change	Long term variations in global temperature and weather patterns caused by natural and human actions.
Culvert	A channel or pipe that carries water below the level of the ground.
Defra	Government Department for Environment, Food and Rural Affairs
DEM	Digital Elevation Model: a topographic model consisting of terrain elevations for ground positions at regularly spaced horizontal intervals. DEM is often used as a global term to describe DSMs (Digital Surface Model) and DTMs (Digital Terrain Models).
Dendritic	Irregular stream branching, with tributaries joining the main stream at all angles. e.g. drainage networks converge into larger trunk sewers and finally one outfall.
DG5 Register	A water-company held register of properties which have experienced sewer flooding due to hydraulic overload, or properties which are 'at risk' of sewer flooding more frequently than once in 20 years.
DSM	Digital Surface Model: a topographic model of the bare earth/underlying terrain of the earth's surface including objects such as vegetation and buildings.
DTM	Digital Terrain Model: a topographic model of the bare earth/underlying terrain of the earth's surface excluding objects such as vegetation and buildings. DTMs are usually derived from DSMs.
EA	Environment Agency, Government Agency reporting to DEFRA charged with protecting the Environment and managing flood risk in England.

Term	Definition
Indicative Flood Risk Areas	Areas determined by the Environment Agency as potentially having a significant flood risk, based on guidance published by Defra and WAG and the use of certain national datasets. These indicative areas are intended to provide a starting point for the determination of Flood Risk Areas by LLFAs.
Internal Drainage Boards	Is an operating authority which is established in areas of special drainage need in England and Wales with permissive powers to undertake work to secure clean water drainage and water level management within a drainage district/
FCERM	Flood and Coastal Erosion Risk Management Strategy. Prepared by the Environment Agency in partnership with Defra. The strategy is required under the Flood and Water Management Act 2010 and will describe what needs to be done by all involved in flood and coastal risk management to reduce the risk of flooding and coastal erosion, and to manage its consequences.
Flood defence	Infrastructure used to protect an area against floods such as floodwalls and embankments; they are designed to a specific standard of protection (design standard).
Flood Risk Area	See entry under Indicative Flood Risk Areas.
Flood Risk Regulations	Transposition of the EU Floods Directive into UK law. The EU Floods Directive is a piece of European Community (EC) legislation to specifically address flood risk by prescribing a common framework for its measurement and management.
Flood and Water Management Act	An Act of Parliament which forms part of the UK Government's response to Sir Michael Pitt's Report on the Summer 2007 floods, the aim of which is to clarify the legislative framework for managing surface water flood risk in England. The Act was passed in 2010 and is currently being enacted.
Fluvial Flooding	Flooding resulting from water levels exceeding the bank level of a watercourse (river or stream). In this report the term Fluvial Flooding generally refers to flooding from Main Rivers (see later definition).
FMfSW	Flood Map for Surface Water. A national data set held by the Environment Agency showing areas where surface water would be expected to flow or pond, as a result of two different chances of rainfall event, the 1 in 30yr and 1 in 200yr events.
FRR	Flood Risk Regulations, see above.
Hyetogrpah	A graphical representation of the variation of rainfall depth or intensity with time.
IDB	Internal Drainage Board. An independent body with powers and duties for land drainage and flood control within a specific geographical area, usually and area reliant on active pumping of water for its drainage.
IUD	Integrated Urban Drainage, a concept which aims to integrate different methods and techniques, including sustainable drainage, to effectively manage surface water within the urban environment.
LDF	Local Development Framework, is the spatial planning strategy introduced in England and Wales by the Planning and Compulsory Purchase Act 2004 and given detail in Planning Policy Statements 12. These documents typically set out a framework for future development and redevelopment within a local planning authority.
LFRZ	Local Flood Risk Zone, see below.
Local Flood Risk Zone	Local Flood Risk Zones are defined as discrete areas of flooding that do not exceed the national criteria for a 'Flood Risk Area' but still affect houses, businesses or infrastructure. A LFRZ is defined as the actual spatial extent of predicted flooding in a single location
Lead Local Flood Authority	Local Authority responsible for taking the lead on local flood risk management. The duties of LLFAs are set out in the Floods and Water Management Act.

Term	Definition
LiDAR	Light Detection and Ranging, a technique to measure ground and building levels remotely from the air, LiDAR data is used to develop DTMs and DEMs (see definitions above).
LLFA	Lead Local Flood Authority, see above.
Local Resilience Forum	A multi-agency forum, bringing together all the organisations that have a duty to cooperate under the Civil Contingencies Act, and those involved in responding to emergencies. They prepare emergency plans in a co-ordinated manner and respond in an emergency. Roles and Responsibilities are defined under the Civil Contingencies Act.
LPA	Local Planning Authority, see below.
Local Planning Authority	The local authority or Council that is empowered by law to exercise planning functions for a particular area. This is typically the local Borough or district Council.
LRF	Local Resilience Forum, see above.
Main River	Main rivers are a statutory type of watercourse in England and Wales, usually larger streams and rivers, but also include some smaller watercourses. A main river is defined as a watercourse marked as such on a main river map, and can include any structure or appliance for controlling or regulating the flow of water in, into or out of a main river. The Environment Agency's powers to carry out flood defence works apply to main rivers only.
NRD	National Receptor Dataset – a collection of risk receptors produced by the Environment Agency. A receptor could include essential infrastructure such as power infrastructure and vulnerable property such as schools and health clinics.
Ordinary Watercourse	All watercourses that are not designated Main River, and which are the responsibility of Local Authorities or, where they exist, IDBs are termed Ordinary Watercourses.
PA	Policy Area, see below.
Partner	A person or organisation with responsibility for the decision or actions that need to be taken.
PFRA	Preliminary Flood Risk Assessment, see below.
Pitt Review	Comprehensive independent review of the 2007 summer floods by Sir Michael Pitt, which provided recommendations to improve flood risk management in England.
Pluvial Flooding	Flooding from water flowing over the surface of the ground; often occurs when the soil is saturated and natural drainage channels or artificial drainage systems have insufficient capacity to cope with additional flow.
Policy Area	One or more Critical Drainage Areas linked together to provide a planning policy tool for the end users. Primarily defined on a hydrological basis, but can also accommodate geological concerns where these significantly influence the implementation of SuDS
PPS25	Planning and Policy Statement 25: Development and Flood Risk
Preliminary Flood Risk Assessment	Assessment required by the EU Floods Directive which summarises flood risk in a geographical area. Led LLFAs.
Resilience Measures	Measures designed to reduce the impact of water that enters property and businesses; could include measures such as raising electrical appliances.
Resistance Measures	Measures designed to keep flood water out of properties and businesses; could include flood guards for example.
Risk	In flood risk management, risk is defined as a product of the probability or likelihood of a flood occurring, combined with the consequence of the flood.
Risk Management Authority	As defined by the Floods and Water Management Act. These can be (a) the Environment Agency,(b) a lead local flood authority, (c) a district council for an area for which there is no unitary authority, (d) an internal drainage board,(e) a water company, and (f) a highway authority.

Term	Definition
RMA	Risk Management Authority, see above
Sewer flooding	Flooding caused by a blockage or overflowing in a sewer or urban drainage system.
SFRA	Strategic Flood Risk Assessment, see below
Stakeholder	A person or organisation affected by the problem or solution, or interested in the problem or solution. They can be individuals or organisations, includes the public and communities.
Strategic Flood Risk Assessment	SFRAs (SFCAs in Wales) are prepared by local planning authorities (in consultation with us) to help guide local planning. They allow them to understand the local risk of flooding from all sources (including surface water and groundwater). They include analysis and maps of the impact of climate change on the extent of future floods. You can find these documents on the website of your local planning authority.
SuDS	Sustainable Drainage Systems, see below.
Sustainable Drainage Systems	Methods of management practices and control structures that are designed to drain surface water in a more sustainable manner than some conventional techniques. Includes swales, wetlands, bioretention devices and ponds.
Surface water	Rainwater (including snow and other precipitation) which is on the surface of the ground (whether or not it is moving), and has not entered a watercourse, drainage system or public sewer.
SWMP	Surface Water Management Plan
TE2100	The Thames Estuary 2100 Project. Led by the Environment Agency, the project was established in 2002 with the aim of developing a long-term tidal flood risk management plan for London and the Thames estuary.
UKCIP	The UK Climate Impacts Programme. Established in 1997 to assist in the co-ordination of research into the impacts of climate change. UKCIP publishes climate change information on behalf of the UK Government and is largely funded by Defra.
WaSC	Water and Sewerage Company
Water Cycle Strategy	A method for determining what sustainable water infrastructure is required and where and when it is needed; based on a risk based approach ensuring that town and country planning makes best use of environmental capacity and opportunities, and adapts to environmental constraints.
WCS	Water Cycle Strategy (see above)

Abbreviations

Term	Definition
AEP	Annual Exceedance Probability
AMP	Asset Management Plan
AStGWF	Areas Susceptible to Ground Water Flooding
AStSWF	Areas Susceptible to Surface Water Flooding
BCKLWN	Borough Council of King's Lynn and West Norfolk
BGS	British Geological Survey
CFMP	Catchment Flood Management Plan
CIRIA	Construction Industry Research and Information Association
CDA	Critical Drainage Area
CLG	Government Department for Communities and Local Government
Defra	Department for Environment, Food and Rural Affairs
DEM	Digital Elevation Model
DTM	Digital Terrain Model
EA	Environment Agency
FGS	Flood Guidance Statement
FMfSW	Flood Map for Surface Water
FRR	Flood Risk Regulations
FWMA	Flood and Water Management Act 2010
IDB	Internal Drainage Board
IUD	Integrated Urban Drainage
JCS	Joint Core Strategy
LDF	Local Development Framework
LiDAR	Light Detection and Ranging
LLFA	Lead Local Flood Authority
LPA	Local Planning Authority
LRF	Local Resilience Forum
NCC	Norfolk County Council
NRD	National Receptor Dataset
PFRA	Preliminary Flood Risk Assessment
PPS25	Planning Policy Statement 25: Development and Flood Risk
RMA	Risk Management Authority (as defined by the Flood and Water Management Act)
SFRA	Strategic Flood Risk Assessment
SuDS	Sustainable Drainage Systems
SWMP	Surface Water Management Plan

Table of Contents

1 Introduction

Capita Symonds have been commissioned by the Borough Council of King's Lynn and West Norfolk (hereinafter referred to as the Borough) and Norfolk County Council to prepare a Surface Water Management Plan (SWMP) for specific settlements within the Borough Council of King's Lynn and West Norfolk administration area which covers Phases 2, 3 and 4 of the Defra guidance.

1.1 What is a Surface Water Management Plan?

A Surface Water Management Plan (SWMP) is a framework to help understand the causes of surface water flooding and agree a preferred strategy for the management of surface water flood risk. In this context, surface water flooding describes flooding caused by runoff from land, roads, buildings, small watercourses and ditches as a result of heavy rainfall.

This SWMP study has been undertaken in consultation with key local partners who have worked together to understand the causes and effects of surface water flooding and agree the most cost effective way of managing surface water flood risk in the long term. This study also establishes a long term action plan to manage surface water and will influence future capital investment, maintenance, public engagement and understanding, land-use planning, emergency planning and future developments. The methodology for this SWMP has been based on the Defra SWMP Technical Guidance, published in March 2010. The guidance document identifies four clear phases in undertaking a SWMP study: Preparation; Risk Assessment; Options; and Implementation and Review. These phases and their key components are illustrated in Figure 1-1 and summarised in Figure 1-2.

Figure 1-1 Recommended Defra SWMP Process (Source Defra 2010)

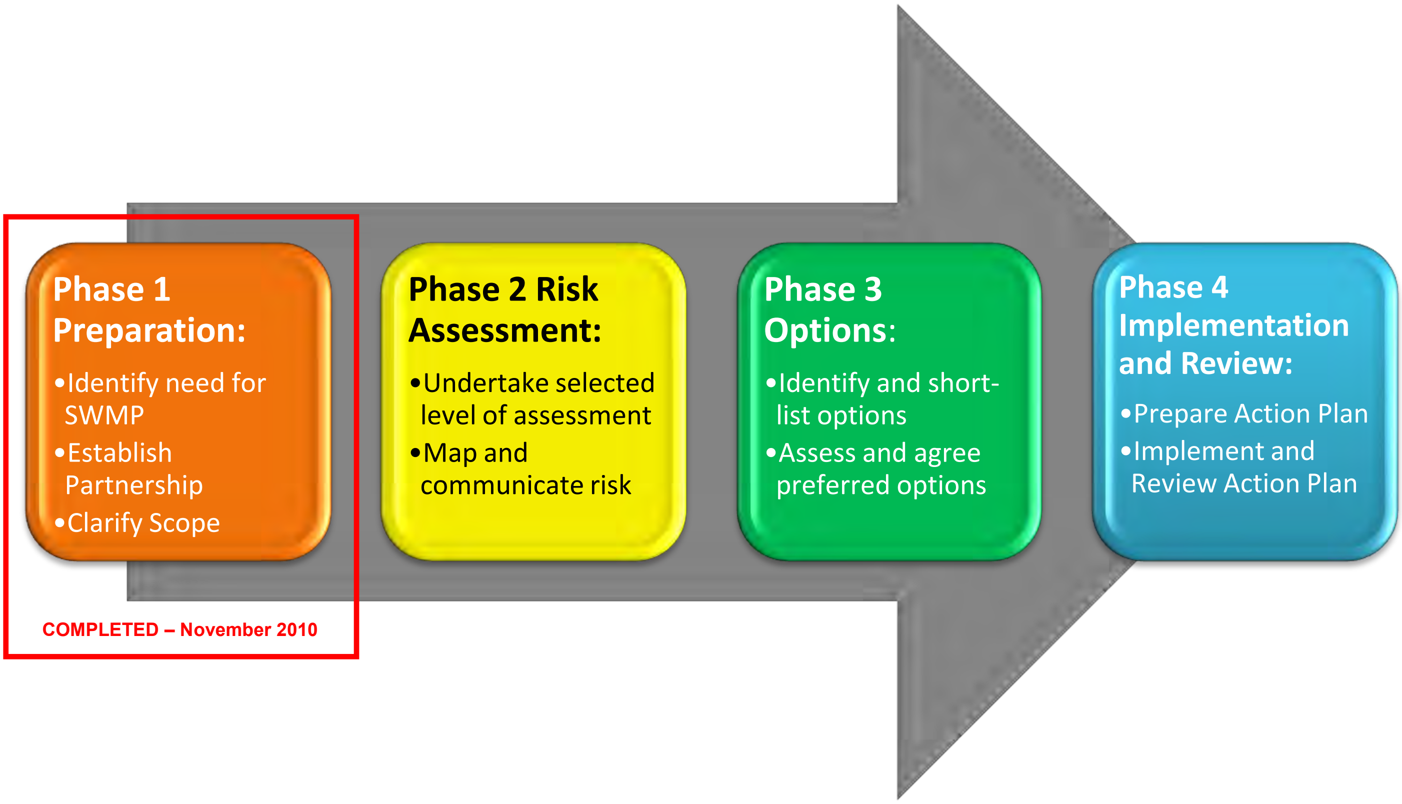


Figure 1-2 Summary of the Defra SWMP Phases

1.2 Background

The Flood and Water Management Act 2010 (FWMA) presented a number of challenges for policy makers and flood risk management authorities identified to coordinate and deliver local flood risk management (including flooding from surface water, groundwater and ordinary watercourses). Lead Local Flood Authorities (LLFAs) have been empowered to manage local flood risk through new responsibilities for flooding from these local sources.

The FWMA reinforced the need to manage flooding holistically and in a sustainable manner, which has grown from the key principles within Making Space for Water (Defra, 2005) and was further reinforced by the summer 2007 floods and the subsequent Pitt Review (Cabinet Office, 2008). The Pitt Review examined the flooding of 2007 and made a range of recommendations for future flood risk management; most of these have been implemented through the Flood and Water Management Act. The preparation of SWMPs was one of the recommendations of the Pitt Review aimed at forming the basis for managing local flood risk in the future.

1.3 Review of Phase 1

Phase 1 (Preparation) of the Surface Water Management Plan was completed on behalf of the Council in November 2010. The key outcomes from this phase of work included:

- Preparing and scoping the requirements for a SWMP;
- Establishing partnerships and clarifying the roles and responsibilities of each partner;
- Identifying the availability of relevant information and where data gaps exist; and
- Identifying the level of assessment of the SWMP study.

1.4 Objectives of Phases 2, 3 and 4

The key aims and objectives of Phases 2, 3 and 4, covered by this report, are summarised below:

Phase 2 – Risk Assessment

- Undertake site inspections of 17 settlements across the Borough to determine those at greatest risk of surface water flooding, and those that require surface water modelling;
- Determine a suitable modelling approach to enable an intermediate assessment of surface water flood risk across the settlements identified from the site assessments;
- Quantify the risks from surface water flooding through the identification of overland flow paths and areas of surface water ponding, leading to the identification of Local Flood Risk Zones (LFRZ);
- Analyse the risks from surface water flooding through an assessment of properties and infrastructure at risk; and
- Map the results of the pluvial modelling and communicate the risk of flooding to relevant bodies within the Client Task Group.

Phase 3 – Options

- Identify borough-wide options for surface water management across the identified modelled settlements, for further investigation; and
- Provide potential option recommendations for un-modelled settlements.

Phase 4 – Implementation and Review

- Prepare action plan; and
- Implement and review SWMP.

1.5 Partnership

The Flood and Water Management Act 2010 defines the Lead Local Flood Authority (LLFA) for an area as the unitary authority for the area, in this case the Norfolk County Council (NCC) represent the upper tier authority for the area. As such, the NCC is responsible for leading local flood risk management including establishing effective partnerships with stakeholders such as the Borough, Environment Agency, Anglian Water, Highways Agency, Network Rail and local Internal Drainage Boards as well as others. Ideally these working arrangements should be formalised to ensure clear lines of communication, mutual co-operation and management through the provision of Level of Service Agreements (LoSA) or Memorandums of Understanding (MoU). It is recommended that the partnerships created as part of the SWMP work are maintained into perpetuity.

Members of the public may also have valuable information to contribute to the SWMP and to an improved understanding and management of local flood risk within the Borough. Public engagement can afford significant benefits to local flood risk management including building trust, gaining access to additional local knowledge and increasing the chances of stakeholder acceptance of options, and decisions proposed in future flood risk management plans.

1.6 Stakeholder Engagement

In order to provide an integrated approach to surface water management, it is important that key stakeholders with responsibility for different flood mechanisms are able to work together in a holistic manner. To this end, key stakeholders have been engaged throughout the duration of this study through the establishment of a Client Task Group, which contains representatives from the organisations illustrated in Figure 1-3. These groups have been consulted throughout the SWMP process and have provided key input at a number of stages of the study.

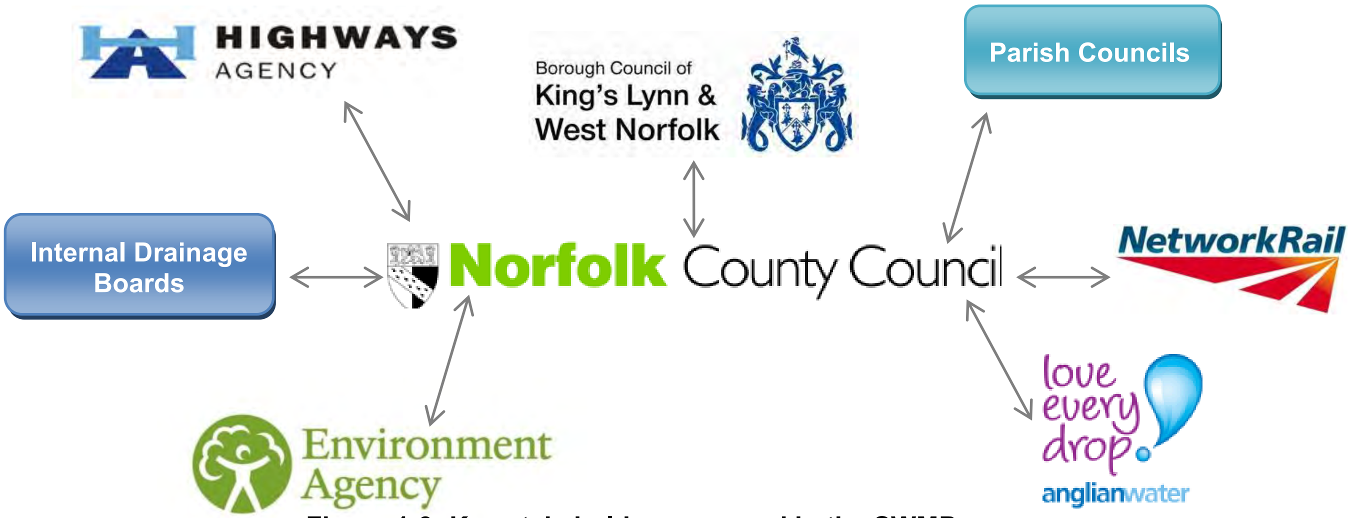


Figure 1-3: Key stakeholders engaged in the SWMP process

1.7 Study Area

The King's Lynn and West Norfolk Council boundary covers an area over 1,508km^2. Due to the large spatial extent, the study area (for this SWMP) has been limited to 17 settlements in order to determine those at greatest risk of surface water flooding as well as those which would benefit from a surface water runoff model being created to determine more accurate flood depth and hazard information. The assessment for selecting which settlements were modelled is discussed within Section 2 of this report.

The Borough Council of King's Lynn and West Norfolk is a second tier local authority in which Norfolk County Council are the upper tier local authority and responsible for delivering the Lead Local Flood Authority (LLFA) requirements of the FWMA in the King's Lynn and West Norfolk area. There are over 100 Parish Councils within the Borough boundary. The spatial extent of the study area along with the 17 settlements assessed within this SWMP is illustrated in Figure 1-4, overleaf.

Location and Characteristics

The Borough is located in the west of Norfolk, and borders the eastern shoreline of The Wash. The area is primarily rural in nature, dominated by arable farming. The largest settlement is King's Lynn, followed by Downham Market in the south and Hunstanton to the north on the coast, as well as a large number of smaller settlements – of which a total of 17 have been assessed within this SWMP. The Borough is largely low lying and includes a large part of fenland where the landscape is dominated by drainage channels managed by Internal Drainage Boards. The study area is at the downstream end of the Great Ouse catchment that drains a large portion of Eastern England (there also are a number of smaller rivers in the area). The area also includes Greensand and Chalk aquifers. Figure 1-5 (and Figures 2.0 – 2.5, within Appendix C), overleaf, provides an overview of the land uses within the Borough.

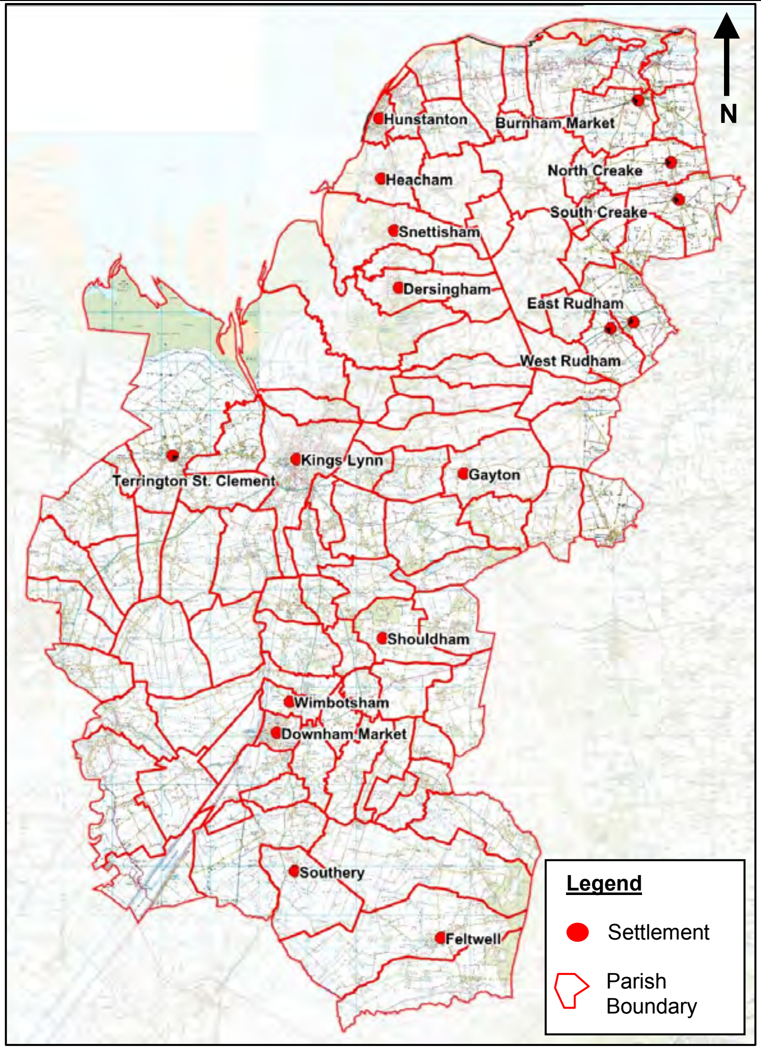


Figure 1-4 Assessed Settlements within the Borough and Local Parish boundaries

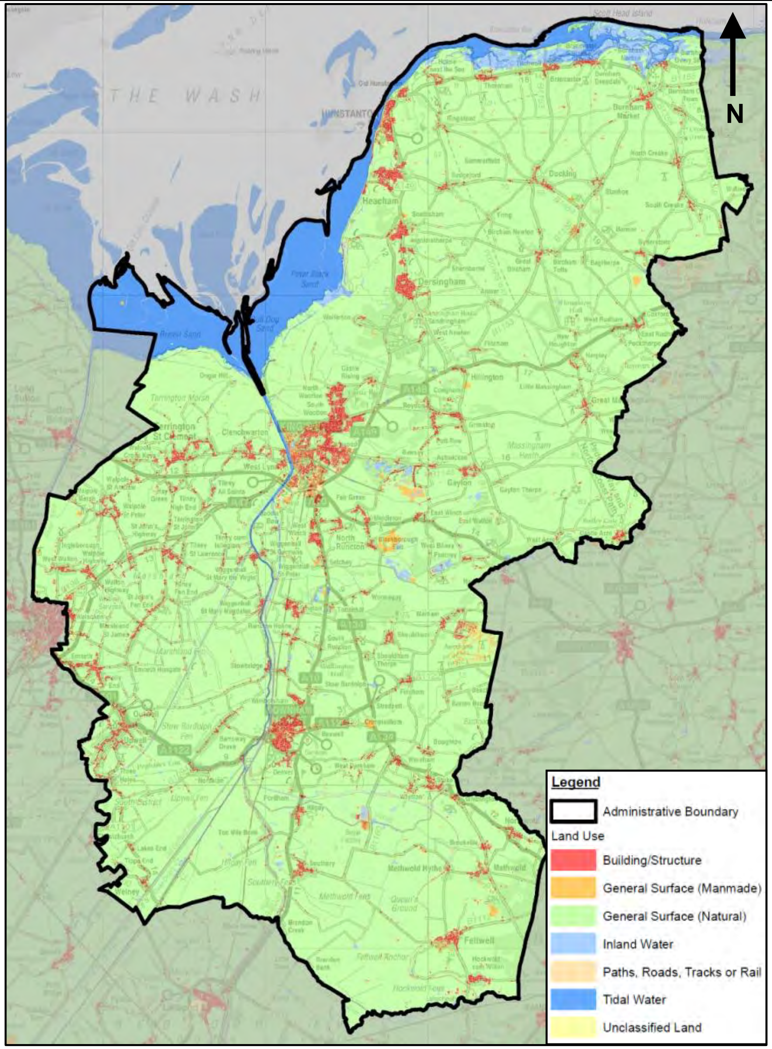


Figure 1-5 Land Uses within the Borough

Major Rivers and Waterways within the Borough

There are several watercourses that flow within the boundary of the Borough. The main watercourses are identified within Table 1-1 and Figure 1-6 (refer to Appendix C for more detailed maps).

Table 1-1 Main Watercourses within King's Lynn and West Norfolk

Watercourse	Closest SWMP Settlement
River Hun	Hunstanton
River Heacham	Heacham
River Ingol	Snettisham
River Burn	Burnham Market, North Creake and South Creake
River Tat	East Rudham
Babingley Brook	King's Lynn
River Nar	King's Lynn
River Great Ouse (Tidal)	King's Lynn and Downham Market
Relief Channel	King's Lynn and Downham Market
Ely Ouse	Southery
Cut-Off Drain	Feltwell

The River Great Ouse, which drains an extensive upland catchment covering much of Buckinghamshire, Bedfordshire and Cambridgeshire, is one of the major rivers of Eastern England and flows from south to north through the western side of the Borough of King's Lynn & West Norfolk. Almost the whole of the Borough south of Kings Lynn, including its tributaries, the Rivers Nar, Wissey and Ely Ouse, falls within its catchment. North of King's Lynn, the small chalk streams drain either to the Wash or to the North Sea.

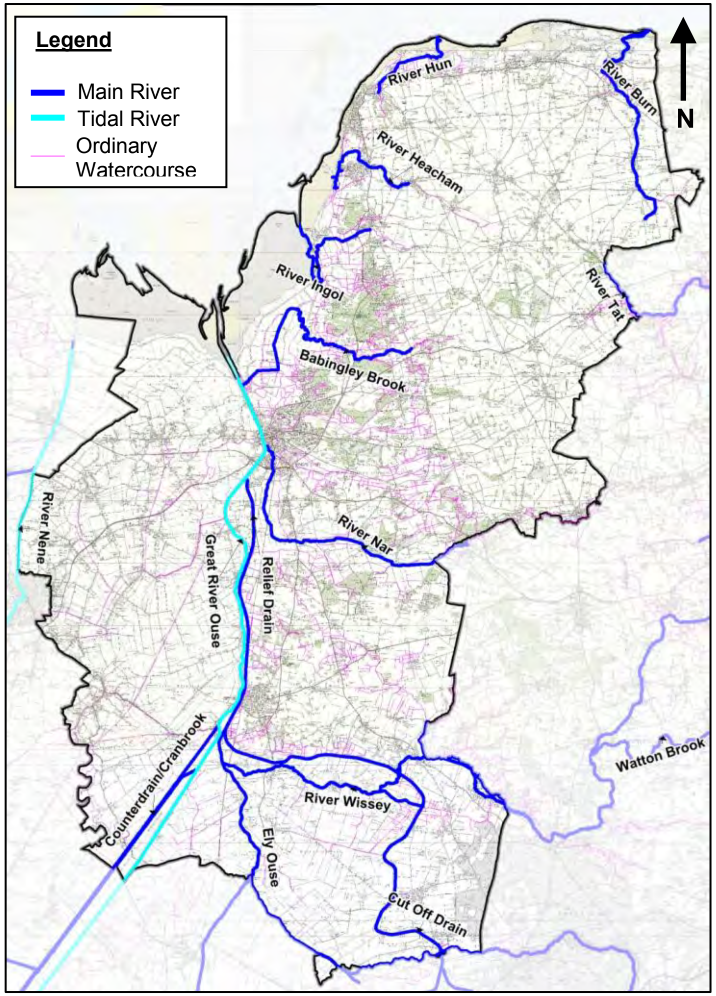


Figure 1-6 Main Watercourses within King's Lynn and West Norfolk

Topography and Geology

The Borough of King's Lynn & West Norfolk encompasses a wide variety of landforms, ranging from relatively narrow stream valleys in the chalk uplands in the north east of the district, through the broader and relatively flat river valleys of the Nar and Wissey south east of King's Lynn, to the extensive areas of fenland in the central area (west of the Great Ouse) and the fens of the south east of the Borough.

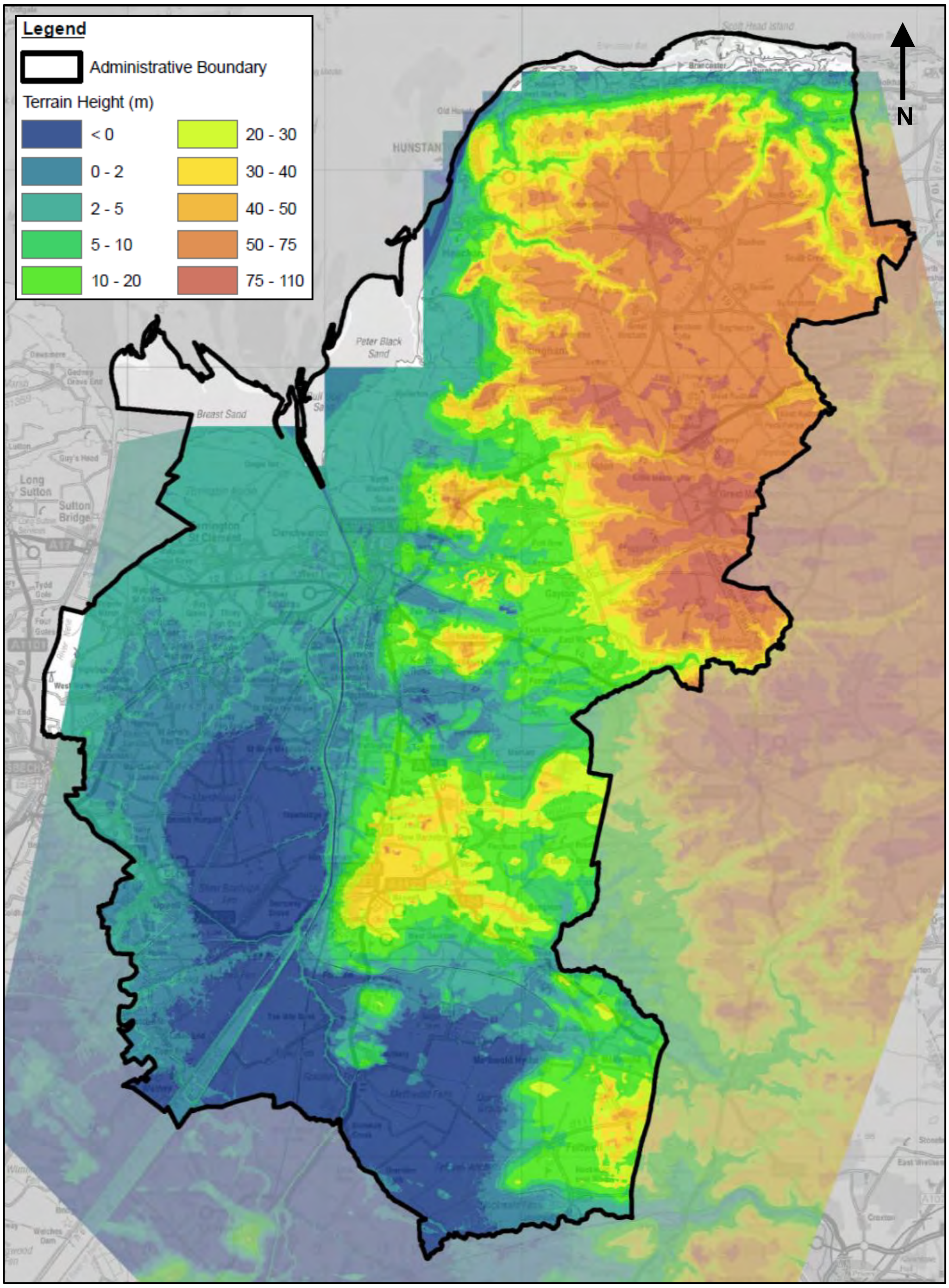


Figure 1-7 DTM Representation of the Topography within the Borough

The bedrock geology of the Borough is primarily split between clay and chalk, with large areas of Kimmeridge Clay in the west and the Upper Chalk Formation in the east. Intermediate areas primarily comprise alluvium, sand and gravel. The nature of the underlying geology affects the potential for groundwater flooding as well as the surface water drainage mechanisms and possible mitigation actions. Chalk sub-strata, indicating the presence of groundwater, can be linked to a heightened risk of groundwater flooding but also enables the use of infiltrating sustainable drainage (SuDS) features to reduce runoff volumes from urban areas. Conversely, clay substrata inhibits the use of infiltrating SuDS features but also indicates a lower risk of groundwater flooding due to the inherent absence of large bodies of groundwater.

1.8 Significant future development plans

The Local Development Framework (LDF) for King's Lynn and West Norfolk identifies a series of growth and regeneration priority areas and places within the borough.

The LDF Core Strategy was adopted in July 2011. It sets the strategic context for planning in the Borough over the period to 2026 and contains a locational strategy and strategic policies on sustainable development and other environmental requirements. A site allocations and policies development plan document is being prepared. Issues and options consultation took place between September and November 2011. The detailed site allocations will be guided by the findings of the SWMP.

1.9 Sources of Flooding

The SWMP technical guidance (Defra 2010) identifies four primary sources of surface water flooding that should be considered within a SWMP as described below:

- **Pluvial flooding**: High intensity storms (often with a short duration) are sometimes unable to infiltrate into the ground or be drained by formal drainage systems since the capacity of the collection systems is not large enough to convey runoff to the underground pipe systems (which in turn might already be surcharging). The pathway for surface water flooding can include blockage, restriction of flows (elevated grounds), overflows of the drainage system and failure of sluice outfalls and pump systems.
- **Sewer flooding**: Flooding which occurs when the capacity of the underground drainage network is exceeded, resulting in the surcharging of water into the nearby environment (or within internal and external building drainage networks). The discharge of the drainage network into waterways and rivers can also be affected if high water levels in receiving waters obstruct the drainage network outfalls.
- **Ordinary Watercourses**: Flooding from small open channels and culverted urban watercourses (which receive most of their flow from the urban areas) can either exceed their capacity and cause localised flooding of an area or can be obstructed (through debris or illegal obstruction) and cause localised out of bank flooding of nearby low lying areas.
- **Groundwater flooding:** Flooding occurs when the water level within the groundwater aquifer rises to the surface. In very wet winters these rising water levels may lead to flooding of areas that are normally dry. This can also lead to streams that only flow for part of the year being reactivated. These intermittent streams are typically known as 'bournes'. Water levels below the ground can rise during winter (dependant on rainfall) and fall during drier summer months as water discharges from the saturated ground into nearby watercourses.

Figure 1-8 provides an illustration of these flood sources. Each of these sources of flood risk are further explained within Section 2 of this report.

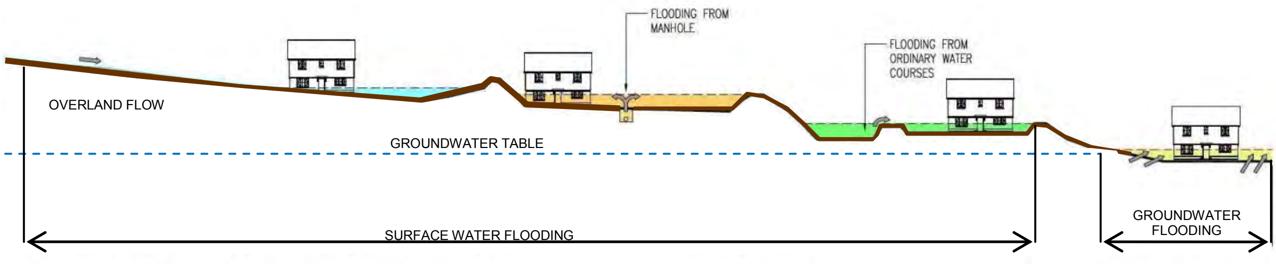


Figure 1-8 Illustration of Flood Sources[1]

1.10 Links with Other Studies

It is important that the SWMP is not viewed as an isolated document, but one that connects with other strategic and local plans. It is also important that it fits in with other studies and plans and does not duplicate existing work.

shows an interpretation of the drivers behind the King's Lynn and West Norfolk settlements SWMP, the evidence base and how the SWMP supports the delivery of other key planning and investment processes.

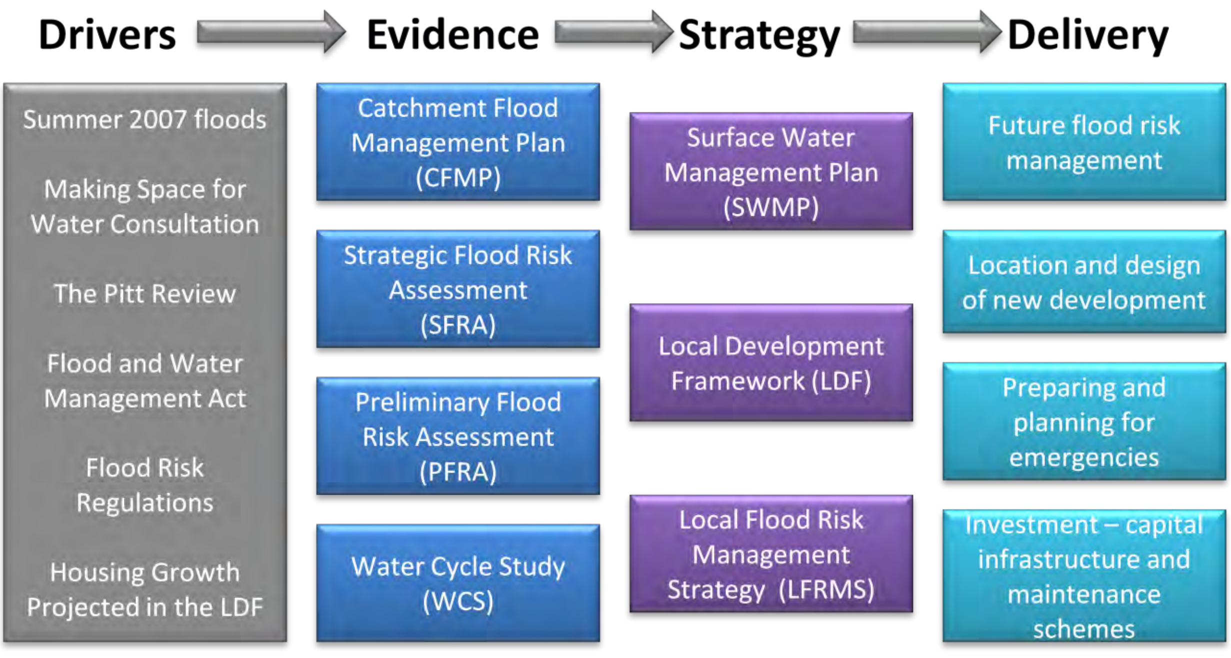


Figure 1-9 Where SWMPs fit in

Figure 1–9, highlights reports compiling evidence on flood risk (CFMP, SFRA, PFRA and WCS) and strategy documents (SWMP and LFRMS). The number of these reports and their nature running parallel to each other has primarily been driven by the timings of their production and data availability; however, the creation and existence of numerous different documents can be confusing.

Some key details for these different studies and plans and how they are relevant to the study area are included below:

[1] Adopted from Thatcham Surface Water Management Plan Volume One

Great Ouse Catchment Flood Management Plan (CFMP)

The Great Ouse Catchment Flood Management Plan (draft, March 2010) and Summary document (January 2011) by the Environment Agency includes the King's Lynn and West Norfolk boundary in its study area. The plan primarily focuses on the risk of flooding from Main Rivers and sets out policies for the sustainable management of flood risk from these sources over the long-term, taking the projected effects of climate change into account. The two relevant policies to this SWMP are:

Policy 2 – Areas of low to moderate flood risk where we can generally reduce existing flood risk management actions. This policy will tend to be applied where the overall level of risk to people and property is low to moderate. It may no longer be value for money to focus on continuing current levels of maintenance of existing defences if we can use resources to reduce risk where there are more people at higher risk. We would therefore review the flood risk management actions being taken so that they are proportionate to the level of risk.

Policy 4 – Areas of low, moderate or high flood risk where we are already managing the flood risk effectively but where we may need to take further actions to keep pace with climate change. This policy will tend to be applied where the risks are currently deemed to be appropriately-managed, but where the risk of flooding is expected to significantly rise in the future. In this case we would need to do more in the future to contain what would otherwise be increasing risk. Taking further action to reduce risk will require further appraisal to assess whether there are socially and environmentally sustainable, technically viable and economically justified options.

The CFMP is intended to be periodically reviewed, approximately five years from when it was published, to ensure that it continues to reflect land use changes in the catchment.

Strategic Flood Risk Assessments (SFRA)

Each local planning authority is required to produce a SFRA under Planning Policy Statement 25 (PPS25). This provides an important tool to guide planning policies and land use decisions. Current SFRAs have a strong emphasis on flooding from main rivers and the sea and are less focussed on evaluating flooding from local sources such as surface water, groundwater and ordinary watercourses; the information from this study will improve this understanding. To date three SFRAs have been produced for the Borough, these are:

- Bullen Consultants (2003) Level 1 Strategic Flood Risk Assessment;
- Faber Maunsell (2008) Revised Level 1 Strategic Flood Risk Assessment; and
- Entec (2010) Level 1 Strategic Flood Risk Assessment Addendum.

It is recommended that future updates to these documents take into account the findings of the SWMP study.

Preliminary Flood Risk Assessment (PFRA)

A Preliminary Flood Risk Assessment for Norfolk County Council, as Lead Local Flood Authority, has been prepared as part of the Flood Risk Regulations. The PFRA process provides a consistent high level overview of the potential risk of flooding from local sources such as surface water, groundwater and ordinary water courses. The outputs from this SWMP will be able to inform future PFRA cycles, which will benefit from an increased level of information and understanding relating to surface water flood risk in the identified settlements of King's Lynn and West Norfolk.

Water Cycle Study (WCS)

A Stage 1 and Stage 2 Water Cycle Study have been completed for the Borough. The objective of a WCS is to provide an integrated approach to managing flood risk, water supply and wastewater infrastructure and to look at potential growth areas in order to identify areas which are suitable for development.

Local Flood Risk Management Strategy (LFRMS)

The Flood and Water Management Act (2010) requires each LLFA to produce a Local Flood Risk Management Strategy for their administrative area. This SWMP will provide a strong evidence base to support the development of the LFRMS within the Borough. As a result of the work as part of this study, no new modelling is anticipated to be required to produce these strategies. Existing studies and plans will be able to support and inform the preparation of a local strategy.

Summary of Documents

The schematic diagram (Figure 1-10, below) illustrates how the CFMP, PFRA, SWMP and SFRA link to and underpin the development of a Local Flood Risk Management Strategy.

Figure 1-10 Links to local strategies

1.11 Existing Legislation

The FWMA 2010 presents a number of challenges for policy makers and the flood and coastal risk management authorities identified to co-ordinate and deliver local flood risk management (surface water, groundwater and flooding from ordinary water courses). 'Upper Tier' local authorities have been empowered to manage local flood risk through new responsibilities for flooding from surface and groundwater.

The FWMA 2010 reinforces the need to manage flooding holistically and in a sustainable manner. This has grown from the key principles within Making Space for Water (Defra, 2005) and was further reinforced by the summer 2007 floods and the Pitt Review (Cabinet Office, 2008). It implements several key recommendations of Sir Michael Pitt's Review of the Summer 2007 floods, whilst also protecting water supplies to consumers and protecting community groups from excessive charges for surface water drainage.

The FWMA 2010 must also be considered in the context of the EU Floods Directive, which was transposed into law by the Flood Risk Regulations 2009 (the Regulations) on 10 December 2009. The Regulations requires three main types of assessment / plan to be produced:

a) Preliminary Flood Risk Assessments (maps and reports for Sea, Main River and Reservoirs flooding) to be completed by LLFA and the Environment Agency by the 22 December 2011. . Flood Risk Areas, at potentially significant risk of flooding, must also be identified. Maps and management plans will be developed on the basis of these flood risk areas. Within the PFRA the LLFA address the local flood risk whilst the Environment Agency provides advice on strategic flood risk.

b) Flood Hazard Maps and Flood Risk Maps. The Environment Agency and LLFA are required to produce Hazard and Risk maps for Sea, Main River and Reservoir flooding as well as 'other' relevant sources by 22 December 2013.

c) Flood Risk Management Plans. The Environment Agency and LLFA are required to produce Flood Risk Management Plans for Sea, Main River and Reservoir flooding as well as 'other' relevant sources by 22 December 2015.

It should be noted that only (a) above is compulsory for all LLFAs. Where an LLFA is not located within a nationally defined 'Flood Risk Area', then (b) and (c) above are not required. Figure 1-11, below, illustrates how this SWMP fits into the delivery of local flood and coastal risk management, and where the responsibilities for this lie.

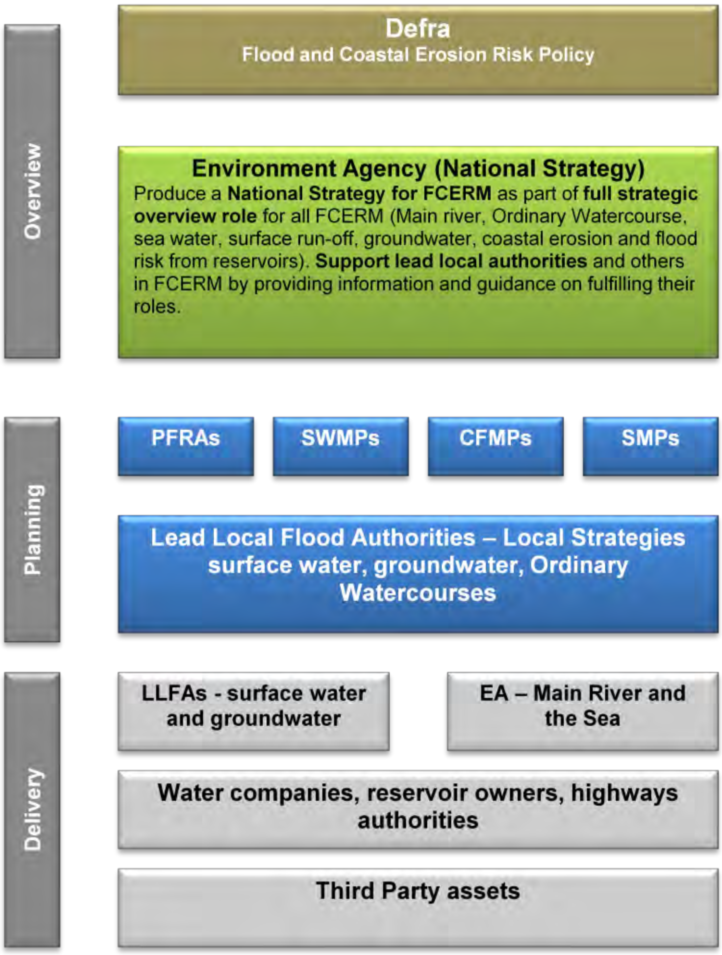


Figure 1-11 Where the SWMP is Located within the Delivery of Local Flood and Coastal Risk Management

1.12 LLFA Responsibilities

In addition to forging partnerships and coordinating and leading on local flood management, there are a number of other key responsibilities that have arisen for Lead Local Flood Authorities from the Flood & Water Management Act 2010, and the Flood Risk Regulations 2009. These responsibilities include:

1. **Investigating flood incidents** – LLFAs have a duty to investigate and record details of significant flood events within their area. This duty includes identifying which authorities have flood risk management functions and what they have done or intend to do with respect to the incident, notifying risk management authorities where necessary and publishing the results of any investigations carried out.

2. **Asset Register** – LLFAs also have a duty to maintain a register of structures or features which are considered to have a significant effect on flood risk, including as a minimum details of ownership and condition. The register must be available for inspection and the Secretary of State will be able to make regulations about the content of the register and records.

3. **SuDS Approving Body** – LLFAs are designated the SuDS Approving Body (SAB) for any new drainage system, and therefore must approve, adopt and maintain any new sustainable drainage systems (SuDS) within their area. This responsibility is anticipated to commence in late 2012.

4. **Local flood risk management strategies** – LLFAs are required to develop, maintain, apply and monitor a strategy for local flood risk management in its area. The local strategy will build upon information such as national risk assessments and will use consistent risk based approaches across different local authority areas and catchments.

5. **Works powers** – LLFAs have powers to undertake works to manage flood risk from surface runoff and groundwater, consistent with the local flood risk management strategy for the area.

6. **Designation powers** – LLFAs, as well as district councils and the Environment Agency, have powers to designate structures and features that affect flooding in order to safeguard assets that are relied upon for flood risk management.

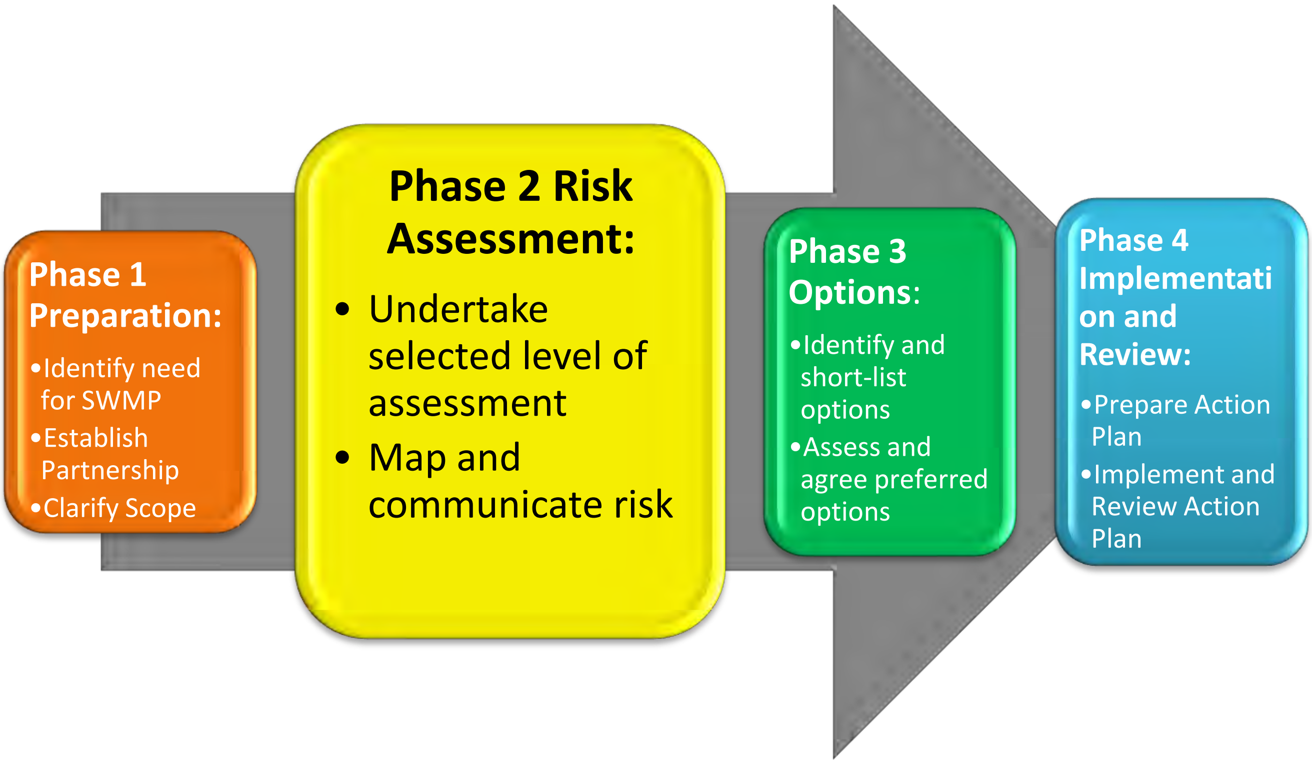
These LLFA requirements have been considered in the production of this document. The SWMP will assist the LLFA in providing evidence for points 1, 2, 3 and 4.

1.13 Local Borough Responsibilities

In order to assist the LLFA in delivering their responsibilities, the Borough Council should undertake the following:

- Maintain ditches and balancing ponds on Borough owned land;
- Enforcing maintenance of land drainage by riparian owners;
- Category One Responder to local and national emergencies;
- Providing temporary accommodation in an emergency; and
- Provision of sand bags in flood events.

PHASE 2: RISK ASSESSMENT



2 Surface Water Flooding

2.1 Overview

Surface water flooding, also known as pluvial flooding or flash flooding, occurs when high intensity rainfall generates runoff which flows over the surface of the ground and ponds in low lying areas. It is usually associated with high intensity rainfall events and can be exacerbated when the ground is saturated (or baked hard) and the drainage network has insufficient capacity to manage the additional flow.

2.2 Historic Flooding

King's Lynn has a history of widespread flooding. The most notable event was the East Coast floods which occurred in 1953. Although this event was predominantly caused by a storm surge, extreme rainfall and subsequent surface water flooding, would have contributed to the damage caused during this event. Figure 2-1 illustrates the impact of these floods within King's Lynn.

Figure 2-1 Flooding in King's Lynn from the 1953 East Coast Floods[2]

The collection of flood history data was undertaken as part of Phase 1 of this study (Mott MacDonald, 2010) and included flood records from different sources including:

- The Borough Council of King's Lynn and West Norfolk;
- Norfolk County Council;
- Norfolk Fire and Rescue Service;
- Norfolk Resilience Forum;

[2] http://www.raf.mod.uk/rafmarham/aboutus/memory11.cfm

- Local Parish Councils; and
- Norfolk Local Climate Impacts Profile (LCIP).

A summary of key historic events which were provided for this report have been geo-referenced and mapped in Figure 2-4.

A significant recent event occurred in the Borough in August 2008, where flooding was reported in a number of areas. Figure 2-2 indicates flooding that occurred along Station Road, Heacham, as a result of this event.

Figure 2-2 Photo of Recent Surface Water Flooding along Station Road, Heacham

2.3 Flood Risk of Identified SWMP Settlements

Due to the spatial extent of the Borough it was agreed that 17 settlements would undergo site inspections to determine which would benefit greatest from hydraulic modelling. These 17 settlements included:

- Burnham Market
- Dersingham
- Downham Market
- East Rudham
- Feltwell
- Gayton
- Heacham
- Hunstanton
- Kings Lynn
- North Creake
- Shouldham
- Snettisham
- South Creake
- Southery
- Terrington St Clement
- West Rudham
- Wimbotsham

Prior to any site inspections, an initial investigation was undertaken in order to assist in the prioritisation of the settlements. This initial review included an assessment of the following:

- Size of the settlement;
- Available historic records;
- Information from public surveys;
- Review of the Stage 1 SWMP findings; and
- A review of Environment Agency flood maps (both the Flood Maps for Surface Water Flooding and the Flood Zone Maps).

Upon completion of the site inspections, the settlements were sorted into three categories:

- Areas that would benefit/require modelling;
- Areas that would benefit from a future review of their drainage infrastructure (no modelling currently required);
- Minimal risk – Maintain existing maintenance regime

The recommendations for each settlement were agreed in consultation with the Client Task Group. The final categories can be seen within Table 2-1 and their locations within the Borough can be seen within Figure 2-3 (overleaf).

Table 2-1 Recommended Approach to Assessment

Modelling recommended	Review of drainage infrastructure	Minimal risk – maintain existing maintenance regime
King's Lynn	Feltwell	East Rudham
Downham Market	Hunstanton	Wimbotsham
Heacham	Burnham Market	Southery
Snettisham	Shouldham	South Creake
	Dersingham	Terrington St Clement
	Gayton	
	West Rudham	
	North Creake	

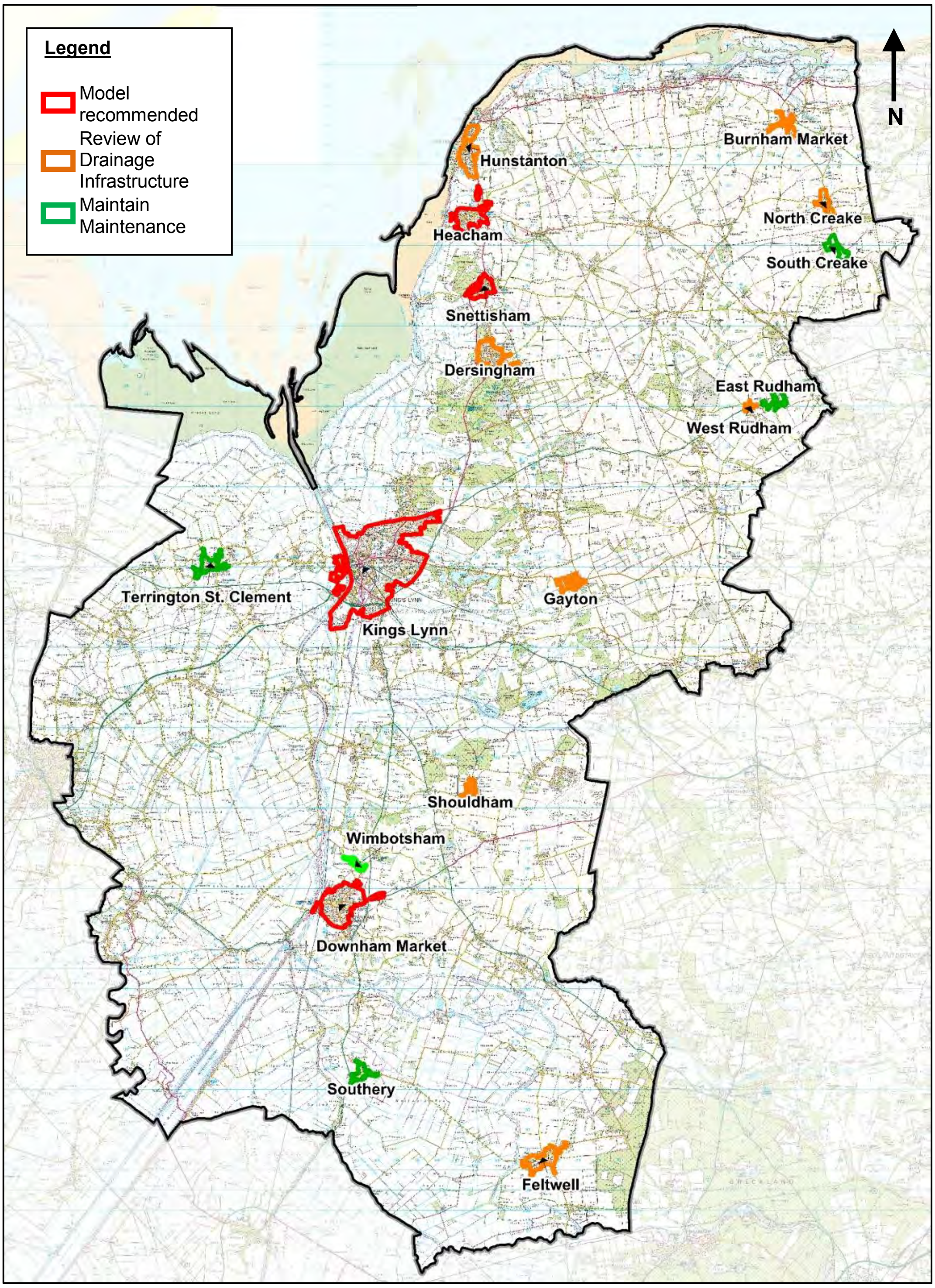


Figure 2-3 Settlement Classification based on Site inspections

2.4 Level of Assessment

SWMPs can function at different geographical scales and as a result of this differing levels of detail may be necessary. Table 2-2 defines the levels of assessment that can be used within a SWMP.

Table 2-2: Level of assessment (adapted from Defra SWMP Guidance, March 2010)

Level of Assessment	Appropriate Scale	Outputs
Strategic Assessment	County or large conurbation (e.g. Norfolk county area)	• Broad understanding of locations that are more vulnerable to surface water flooding. • Prioritised list for further assessment. • Outline maps to inform spatial and emergency planning.
Intermediate Assessment	Large town or city (e.g. King's Lynn)	• Identify flood hotspots which might require further analysis through detailed assessment. • Identify immediate mitigation measures which can be implemented. • Inform spatial and emergency planning.
Detailed Assessment	Known flooding hotspots (e.g. Critical Drainage Areas)	• Detailed assessment of cause and consequences of flooding. • Use to understand the mechanisms and test potential mitigation measures.

2.4.1 Intermediate Assessment

As shown in Table 2-2, an intermediate assessment is applicable across a large town or city, such as the settlements selected within the Phase 2 site assessments. Discussions with the Client Task Group concluded that an intermediate assessment is considered to be an appropriate level of assessment to further quantify the risks within the selected settlements.

The purpose of the intermediate assessment will be to further identify areas within King's Lynn and West Norfolk that are likely to be at greatest risk of surface water flooding and which may require further analysis through more detailed assessment.

The outputs from this assessment should be used to inform spatial and emergency planning. The outputs can also be used to identify potential mitigation measures which can be implemented immediately in order to reduce surface water flood risk. These may include quick win measures such as improving maintenance and clearing blockages/obstruction to the drainage infrastructure.

2.5 Risk Overview

The following sources of flooding have been assessed and are discussed in detail in the following sections of this report:

- Pluvial flooding: runoff as a result of high intensity rainfall when water is ponding or flowing over the ground surface before it enters the underground drainage network or a watercourse.
- Flooding from ordinary watercourses: flooding which occurs as a result of the capacity of the watercourse being exceeded resulting in out of bank flow (water coming back out of rivers and streams).
- Sewer flooding: Flooding which occurs when the capacity of the underground drainage system is exceeded, resulting in flooding inside and outside of buildings. Normal discharge of sewers and drains through outfalls may be impeded by high water levels in receiving waters as a result of wet weather conditions.

- Flooding from groundwater sources: Occurs when the water level within the groundwater aquifer rises to the surface.

The identification of areas at risk of flooding has been dominated by the assessment of surface water and ordinary watercourse flooding as these sources are expected to result in the greater consequence (risk to life and damage to property), as well as by the quality of the information available for informing the assessment.

2.6 Pluvial Flooding

2.6.1 Description

Pluvial flooding is the term used to describe flooding which occurs when intense, often short duration rainfall is unable to soak into the ground or to enter drainage systems and therefore runs over the land surface causing flooding. It is most likely to occur when soils are saturated (or baked hard) so that they cannot infiltrate any additional water or in urban areas where buildings tarmac and concrete prevent water soaking into the ground. The excess water can pond (collect) in low points and result in the development of flow pathways often along roads but also through built up areas and open spaces. This type of flooding is usually short lived and associated with heavy downpours of rain.

The potential volume of surface runoff in catchments is directly related to the size and shape of the catchment to that point. The amount of runoff is also a function of geology, slope, climate, rainfall, saturation, soil type, urbanisation and vegetation.

2.6.2 Causes and classifications

Pluvial flooding can occur in rural and urban areas, but usually causes more damage and disruption in the latter. Flood pathways include the land and water features over which floodwater flows. These pathways can include drainage channels, rail and road cuttings. Developments that include significant impermeable surfaces, such as roads and car parks may increase the volume and rate of surface water runoff.

Urban areas which are close to artificial drainage systems, or located at the bottom of hill slopes, or in valley bottoms and hollows, may be more prone to pluvial flooding. This may be the case in areas that are down slope of land that has a high runoff potential including impermeable areas and compacted ground.

2.6.3 Impacts of pluvial flooding

Pluvial flooding can affect all forms of the built environment, including:

- Residential, commercial and industrial properties;
- Infrastructure, such as roads and railways, electrical infrastructure, telecommunication systems and sewer systems;

It can also impact on:

- Agriculture; and
- Amenity and recreation facilities.

This type of flooding is usually short-lived and may only last as long as the rainfall event. However occasionally flooding may persist in low-lying areas where ponding occurs. Due to the typically short duration, this type of flooding tends not to have consequences as serious as other forms of flooding, such as flooding from rivers; however it can still cause significant damage and disruption on a local scale.

2.6.4 Historic Records – Pluvial Flooding

Past records of surface water flooding within the study area have been gathered from previous studies undertaken for the Borough (SFRA, WCS, Stage 1 SWMP). These incidents have been mapped as part of the SWMP and shown in Figure 2-4 below.

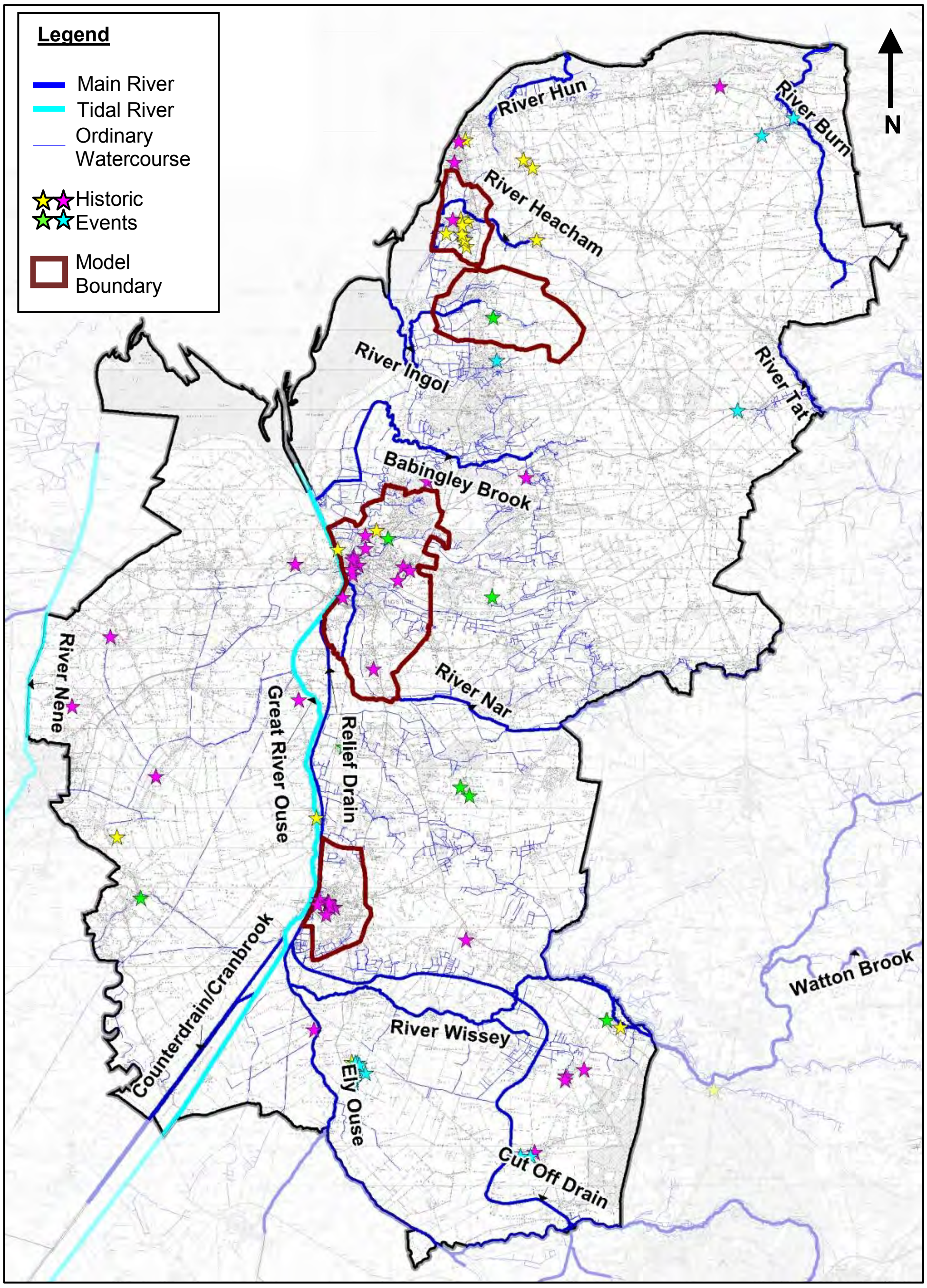


Figure 2-4 Historic Flood Events within the Borough

A review of these records indicates that a majority of these incidents occur within the centre of the larger settlements, which is expected based on the design of the historic drainage network and the amount of urban expansion which has reduced the network's' capacity.

2.6.5 Methodology for Assessment of Pluvial Flooding

Modelling Overview

In order to continue developing an understanding of the causes and consequences of surface water flooding in the study area, intermediate level hydraulic modelling has been undertaken for a range of rainfall event probabilities. The purpose of this modelling is to provide additional information where local knowledge is lacking and forms a basis for future detailed assessments in areas identified as high risk.

The surface water modelling was undertaken using TUFLOW modelling software (TUFLOW Build_2010-10-AC iDP). TUFLOW is a computational engine that provides two-dimensional (2D) solutions of free-surface flow equations used to simulate flood propagation. It is specifically beneficial where the hydrodynamic behaviour and flow patterns in urban drainage environments are complex, as TUFLOW simulates water level variations and flows for depth-averaged unsteady two-dimensional free-surface flows. TUFLOW has been successfully used in many projects to model the flow of water across extensive urban floodplains.

A Direct Rainfall approach (see Table 2-3) has been selected where rainfall events of known probability are applied directly to the ground surface and water is routed overland to provide an indication of potential flow paths and areas where surface water will pond during an extreme event.

Table 2-3: Levels of pluvial modelling

Rolling Ball	Surface water flow routes are identified by topographic analysis, most commonly in a GIS package
Direct Rainfall	Rainfall is applied directly to a surface and is routed overland to predict surface water flooding
Drainage Systems	Based around models of the underground drainage systems
Integrated Approach	Representing both direct rainfall and drainage systems in an integrated manner, or through linking different models together dynamically

To facilitate the accurate review and retrieval of data a number of actions were undertaken, including:

- The use of a standard folder structure for all model files;
- A standardised naming convention that included the model name, grid size, scenario and version number;
- A model log was initiated at the start of the modelling process that provides a clear and concise record of model development; and
- The model was reviewed by a senior modeller following Capita Symonds standard Quality Assurance protocol. This review incorporated all the model files that were used in the model set-up.

As part of the SWMP process, hydraulic modelling has been undertaken for the study area. Two 2-dimensional direct rainfall models were created using TUFLOW software to determine the likelihood, mechanisms and consequences of pluvial flooding. The results of the models provide an indication of key flow paths, velocities and areas where water is likely to pond.

The extents of the models have been based upon catchment boundaries as agreed with the SWMP Client Task group. Four models were required to cover the settlements at the agreed resolution of 5m. Figure 2-5 below, indicates the extent of the models utilised within the risk assessment.

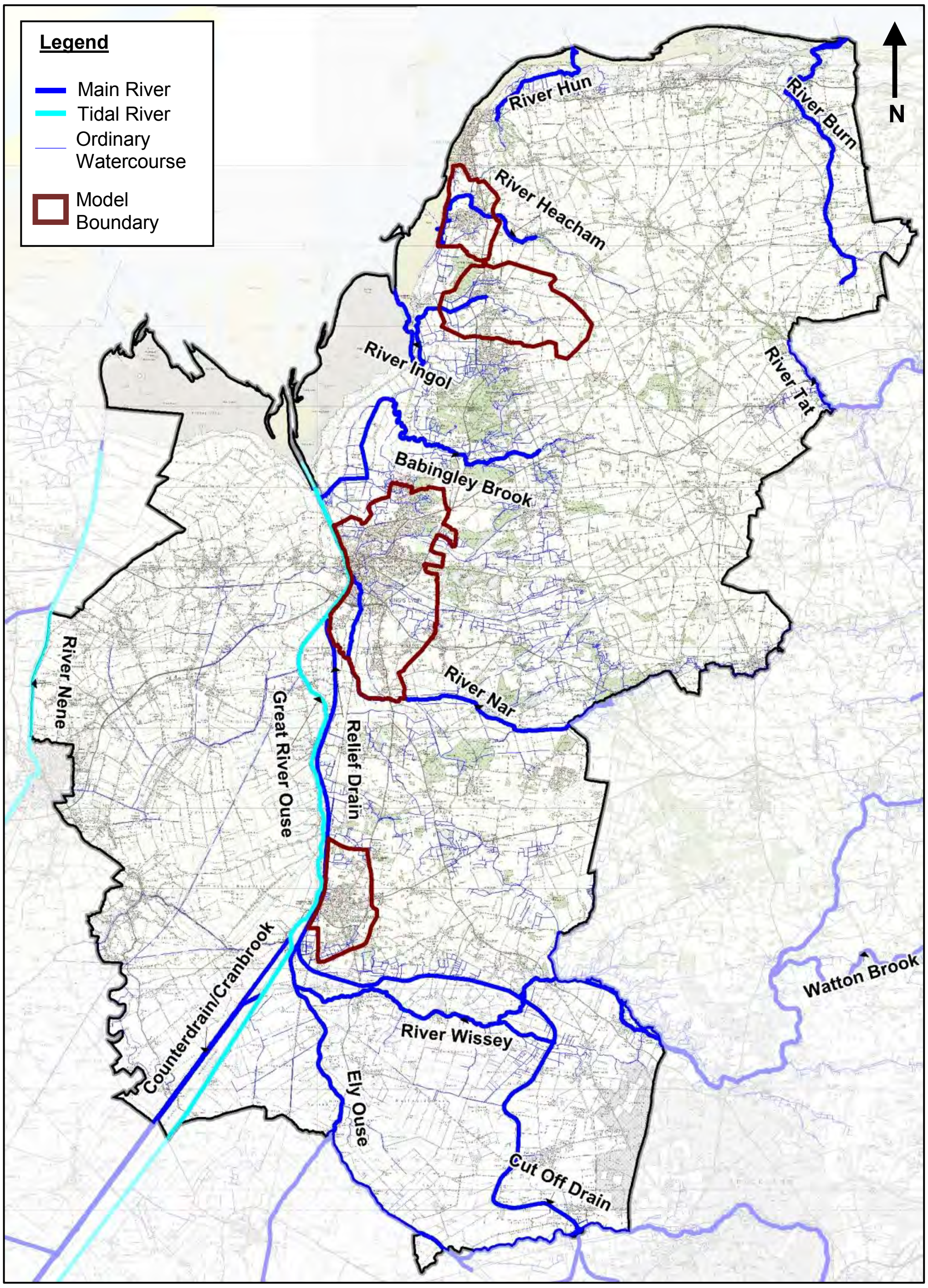


Figure 2-5 TUFLOW Model Boundaries

The selected return periods were chosen through consultation with the steering group. As part of this report, figures have been prepared for the modelled settlements based on the 1 in 100 year rainfall event (1% AEP). GIS layers of results for the remaining return periods have also been produced and are included in Appendix C. Additionally, ASCII grids and ESRI Shape files have been created and distributed to Norfolk County Council and the Borough for use within their in-house GIS system. Table 2-4 provides details of the return periods that have been selected and the suggested uses of the various modelling outputs.

Table 2-4: Selected return periods and suggested use of outputs

Modelled Return Period	Suggested use
1 in 30 year event *(3.3% AEP)*	Anglian Water sewers are (now) typically designed to accommodate rainfall events with a 1 in 30 year return period or less. This layer will identify areas that are prone to regular flooding and could be used by highway teams to inform maintenance regimes.
1 in 75 year event *(1.3% AEP)*	In areas where the likelihood of flooding is 1 in 75 years or greater insurers may not guarantee to provide cover to property if it is affected by flooding. This layer should be used to inform spatial planning as if property cannot be guaranteed insurance, the development may not be viable.
1 in 100 year event *(1% AEP)*	Can be overlaid with Environment Agency Flood Zone 3 layer to show areas at risk under the same event from surface water and main river flooding. Can be used to advise planning teams – please note that the pluvial 1 in 100 year event may differ from the fluvial event due to methods in runoff and routing calculations.
1 in 100 year event (plus climate change)	PPS25 requires that the impact of climate change is fully assessed. Reference should be made to this flood outline by the spatial planning teams to assess the sustainability of developments.
1 in 200 year event *(0.5% AEP)*	To be used by emergency planning teams when formulating emergency evacuation plans from areas at risk of flooding.

A summer rainfall profile was selected as it produces a higher intensity storm event in comparison to a winter profile, which is considered to be the worst-case scenario. Models simulations were run at double the critical duration in order to allow runoff to be conveyed down overland flow paths.

As part of this study, maps of maximum water depth and hazard for each of the return periods above have been prepared and are presented in Appendix C of this report. When viewing the maps, it is important that the limitations of the modelling are considered – refer to key assumptions and uncertainties discusses later in this report.

The figures presented in Appendix C indicate that water is predicted to pond over a number of roads and residential properties. These generally occur at low points in the topography or where water is constricted behind an obstruction or embankment.

Roads and Railway lines with 'cuttings' may also be particularly susceptible, such as the A47 within King's Lynn and the Downham Market Railway Station.

Some of the records of surface water flooding shown in Figure 2-4 have been used to verify the modelling results. Discussions with Council staff have also provided anecdotal support for several of the locations identified as being susceptible to flooding.

The results of the assessment have been used to identify 'Local Flood Risk Zones' (LFRZs) across the study area.

2.6.6 Uncertainty in flood risk assessment – Surface Water Modelling

The surface water modelling provides the most detailed information to date on the mechanisms, extent and hazard which may result from high intensity rainfall across the study area. However, due to the strategic nature of this study and the limitations of some data sets, there are limitations and uncertainties in the assessment approach of which the reader should be aware.

There is a lack of reliable measured datasets and the estimation of the return period (probability) for flood events is therefore difficult to verify. The broad scale mapping provides an initial guide to areas that may be at risk, however there are a number of limitations to using the information:

- The mapping does not include underground sewerage and drainage systems (refer to Section 2.6.7 for the assumptions utilised in this study) ;
- The mapping should not be used in a scale to identify individual properties at risk of surface water flooding. It can only be used as a general indication of areas potentially at risk.
- Whilst modelled rainfall input has been modified to reflect the possible impacts of climate change it should be acknowledged that this type of flooding scenario is uncertain and likely to be very site specific. More intense short duration rainfall and higher more prolonged winter rainfall are likely to exacerbate flooding in the future.

2.6.7 Key Assumptions

The surface water modelling methodology for the Borough has used the following key assumptions:

- An allowance for the drainage capacity of the settlement's' drainage network has been included as a constant loss of 3mm/hour (from impervious surfaces) for the settlements of Downham Market, Heacham and Snettisham to reflect some minor storage within the network during a rain event. This figure was selected in consultation with Anglian Water and the Internal Drainage Boards (IDB's);
- No drainage losses have been applied to the impervious surfaces in King's Lynn in order to better reflect a scenario where the drainage outlets are 'tide locked';
- No pumping stations have been included within the model;
- It has been assumed that land roughness varies with land type (e.g., roads, buildings, grass, water, etc) and therefore different Manning's roughness coefficients have been specified for different land types to represent the effect different surfaces have on the flow of water;
- Watercourses (where easily identifiable of designated by Environment Agency GIS information) within the study area have been modelled as being 'bank full' in order to represent the worst case mechanism for flooding in the Borough;
- Building thresholds have been included in the model in order to represent the influence they have on surface water flow paths. All building polygons within the model were raised by 0.1m, meaning they act as barriers to flood waters in the model, up until the water depth becomes greater than 0.1m where it is assumed that the building would flood and water would flow through the building, as would be the case in an actual flood event;
- Fences and other thin obstructions have not been considered to influence overland flow paths; and

- It has been assumed that no infiltration occurs across the study area – however indirect losses are included as a result of the runoff coefficients utilised within the model. Given the likely intensity of a summer storm this is not considered to be over-conservative.

2.6.8 Hydrology

An important aspect of establishing suitable rainfall profiles is to estimate the critical storm duration for the study area. In order to ensure that the most appropriate scenario is assessed and the entire catchment is contributing surface water runoff, the critical storm duration must be estimated.

Two methods were used to calculate an estimate of the critical storm duration for the rainfall profiles used in the model. A summary of these methods is given below:

- The Bransby-Williams formula was used to derive the *time of concentration,* defined as the time taken for water to travel from the furthest point in the catchment to the catchment outfall, at which point the entire site is considered to be contributing runoff; and
- The Flood Estimation Handbook (FEH) equation for critical storm duration - the standard average annual rainfall (SAAR) value for each a catchment has been extracted from the FEH CD-ROM v3 and the Revitalised Flood Hydrograph method (ReFH) model has been used to derive the time to peak (Tp) from catchment descriptors.

Based on the results from the following critical storm durations were used within the direct rainfall models:

- King's Lynn – 3.4 hours
- Downham Market – 1hour
- Snettisham – 1.4hours
- Heacham – 1.3hours

The catchment descriptors, from the centre of each catchment, were exported from the Flood Estimation Handbook (FEH) into the rainfall generator within Infoworks CS, which was used to derive rainfall hyetographs for a range of return periods. The hyetographs generated using this methodology, and incorporated within the pluvial model can be located within Appendix B.

2.6.9 Model Topography

The boundary of the models was based on a review of the topographical information available for the area. This included the following information (in order of preference):

- Light Detecting and Ranging data (LiDAR) was used as the base information for the model topography. LiDAR data is an airborne survey technique that uses laser to measure the distance between an aircraft and the ground surface, recording an elevation accurate to ±0.15m at points 1m apart (and 2m apart). The technique records elevations from all surfaces and includes features such as buildings, trees and cars. This raw data is then processed to remove these features and provide values of the ground surface, which is merged to create a Digital Terrain Model (DTM) of the ground surface itself; and
- IFSAR (Interferometric Synthetic Aperture) - An aircraft-mounted sensor designed to measure surface elevation, which is used to produce topographic imagery. Sold under the name NEXTmap. Depending on the terrain and vegetation, IFSAR can have a vertical accuracy of ±1m.

Figure 2-6 displays the variation in level of detail available between these datasets.

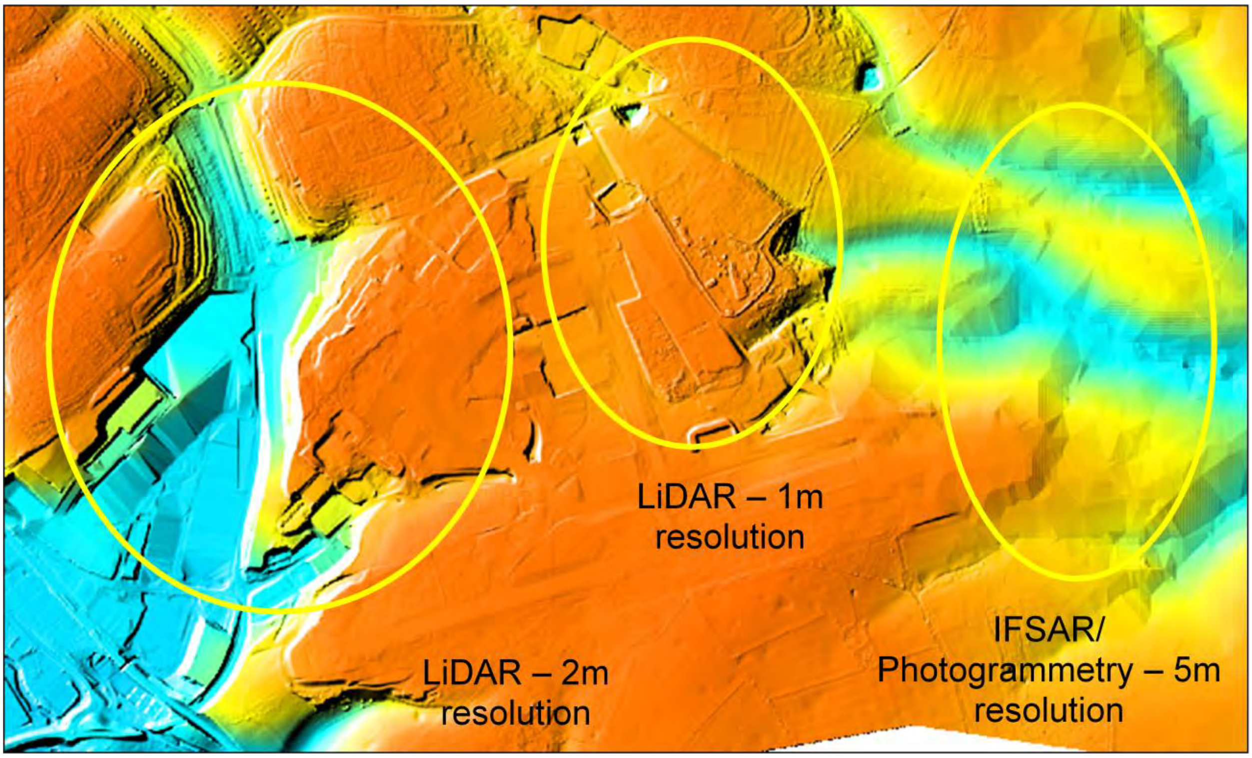


Figure 2-6 Variation in Information utilised to Create the Model DTM

LiDAR data was available at a 1m resolution for the majority of the study area, and in the few small areas it was missing, 2m resolution LiDAR. Where 2m LiDAR was not available, IFSAR was used (in particular the upper catchment of Snettisham) to assist in creating the DTM. Filtered LiDAR (and IFSAR) data (in preference to unfiltered) has been used as the base topography to provide the model with a smoother surface to reduce the potential instabilities in the model and areas of unexpected ponding.

An image of the DTM used to represent the topography of the study area in the pluvial models are shown in Appendix C – the general topography of the Borough can be seen in Figure 1-7.

The ground elevations were represented in TUFLOW using a 5m grid. The decision to use a 5m grid is an optimisation of the computational time required due to the size of the study area and the need for accuracy in the model in order to resolve features in the urban environment.

2.6.10 Land Surface

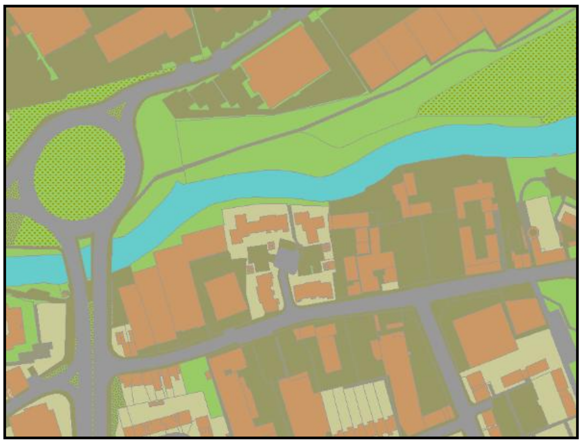


Figure 2-7: OS Mastermap land type layers

The type of land surface has a significant effect on the flow of water along surface water flow paths due to the relatively shallow depths of flooding. As such, a number of roughness coefficients have been specified in order to accurately represent different land types within the hydraulic model and the effect they have on the flow of water.

OS Mastermap data has been used to produce different land type layers (such as roads, grass, water, etc, as shown in Figure 2-7), for which different Manning's roughness coefficients have been specified. These layers have been applied across the modelled areas and included within the TUFLOW model in order to represent the different behaviour of water as it flows over different surfaces.

2.6.11 Model Verification

It is important to ensure that the outputs from the modelling process are as reliable as possible. To this end, a number of actions and data sources have been used to check the validity of the model outputs, including the following:

Ground-truth model

This stage of verification involved reviewing the hydraulic model outputs against the initial site inspections/assessment to ensure that the predictions were realistic and considered local topography and identified drainage patterns. Where previous site inspection data did not provide sufficient information on a specific area within the study, the model outputs were assessed against photography from third party sources (Google and Bing maps) to assist in the model verification.

EA national surface water mapping

The Environment Agency has produced two national surface water datasets using a coarse scale national methodology:

- Areas Susceptible to Surface Water Flooding (AStSWF); and
- Flood Map for Surface Water (FMfSW).

As a method of validation, the outputs from these datasets have been compared to the SWMP modelling outputs to ensure similar flood depths and extents have been predicted. There are slight variations, due to the more accurate methodology used in the SWMP risk assessment, but on the whole the outputs with relation to ponding locations are very similar. However, the extent of the depths was noticed to vary, as shown in the example in Figure 2-8, overleaf. This observation provides confidence in the final model outputs as the variation in the results is concluded as being related to the more refined DTM (used within this study) and the catchment specific critical durations (as the Environment Agency FMfSW maps utilised a single duration to represent runoff throughout England) defined in this report.

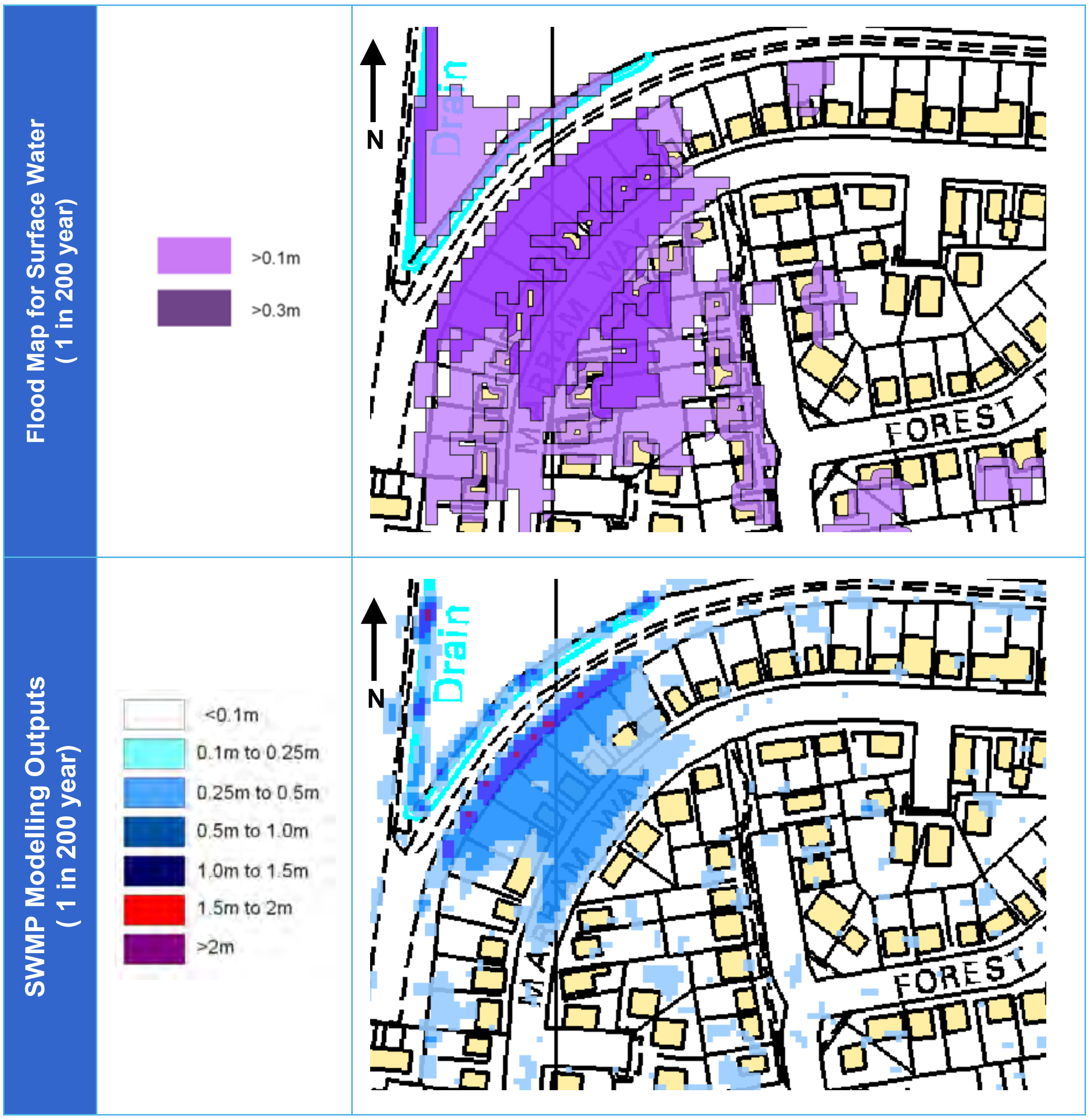


Figure 2-8 Example comparison between FMfSW and SWMP model outputs

Flood history and local knowledge

Recorded flood history has also been used to verify areas which are identified as being at risk of flooding with previous known flood events. As discussed in Section 2.2, information on historical flood events was collected from a number of sources. In addition to this, members of the Client Task Group, have an extensive knowledge of the study area and the drainage and flooding history through living locally.

The use of a stakeholder workshop, with all assessed Council and Parish Council representatives, was also an effective way to validate the model outputs. The members who attended the workshop examined the modelling outputs and were able to provided anecdotal information on past flooding which confirmed several of the predicted areas of ponding. A number of photographs were also provided, which were used to verify the model results, as illustrated in Figure 2-9,overleaf.

Figure 2-9 Validation of model outputs with local information (Station Road, Heacham)

Mass balance checks

The accuracy of the hydraulic calculations driving the TUFLOW model, and the performance of the model itself, can be checked using a simple analysis of the data from the model. The percentage mass error is calculated every five (5) minutes and output with the other results files. The percentage mass error is a mass error based on the maximum volume of water that has flowed through the model and the total volume of water in the model. It is normal for the figure to be large at the start of a simulation, particularly with steep models using the direct rainfall approach, as the cells are rapidly becoming wet as it begins to rain but flow through the model is relatively small. Mass balance graphs can be located within Appendix B.

2.6.12 Model Outputs

TUFLOW outputs data in a format which can be easily exported into GIS packages. As part of the surface water modelling exercise, a series of ASCII grids and MapInfo TAB files have been created including:

- Flood depth grids;
- Flow velocity grids; and
- Flood hazard grids.

Flood hazard is a function of the flood depth, flow velocity and a debris factor (determined by the flood depth). Each grid cell generated by TUFLOW has been assigned one of four hazard rating categories: 'Extreme Hazard', 'Significant Hazard', 'Moderate Hazard' and 'Low Hazard'. Guidance on the depths and velocities (hazard) of floodwater that can be a risk to people is shown within Figure 2-10 (overleaf).

The hazard rating (HR) at each point and at each time step during a flood event is calculated according to the following formula (Defra/Environment Agency FD2320/TR1 report, 2005):

$$HR = d\,(v + 0.5) + DF$$

Where:
- HR = flood hazard rating
- d = depth of flooding (m)
- v = velocity of floodwater (m/s)
- DF = Debris Factor, according to depth, d (see below)

Guidance within the FD2320 report recommends the use of a Debris Factor (DF) to account for the presence of debris during a flood event in the urban environment. The Debris Factor is dependent on the depth of flooding; for depths less than 0.25m a Debris Factor of 0.5 was used and for depths greater than 0.25m a Debris Factor of 1.0 was used.

The maximum hazard rating for each point in the model is then converted to a flood hazard rating category, as described in Table 2-5, overleaf. These are typically classified as caution (very low hazard), moderate (danger for some), significant (danger for most), extreme (danger for all).

HR	Depth of flooding - d (m)												
	DF = 0.5				DF = 1								
Velocity v (m/s)	0.05	0.10	0.20	0.25	0.30	0.40	0.50	0.60	0.80	1.00	1.50	2.00	2.50
0.0	0.03 + 0.5 = 0.53	0.05 + 0.5 = 0.55	0.10 + 0.5 = 0.60	0.13 + 0.5 = 0.63	0.15 + 1.0 = 1.15	0.20 + 1.0 = 1.20	0.25 + 1.0 = 1.25	0.30 + 1.0 = 1.30	0.40 + 1.0 = 1.40	0.50 + 1.0 = 1.50	0.75 + 1.0 = 1.75	1.00 + 1.0 = 2.00	1.25 + 1.0 = 2.25
0.1	0.03 + 0.5 = 0.53	0.06 + 0.5 = 0.56	0.12 + 0.5 = 0.62	0.15 + 0.5 = 0.65	0.18 + 1.0 = 1.18	0.24 + 1.0 = 1.24	0.30 + 1.0 = 1.30	0.36 + 1.0 = 1.36	0.48 + 1.0 = 1.48	0.60 + 1.0 = 1.60	0.90 + 1.0 = 1.90	1.20 + 1.0 = 2.20	1.50 + 1.0 = 2.55
0.3	0.04 + 0.5 = 0.54	0.08 + 0.5 = 0.58	0.15 + 0.5 = 0.65	0.19 + 0.5 = 0.69	0.23 + 1.0 = 1.23	0.30 + 1.0 = 1.30	0.38 + 1.0 = 1.38	0.45 + 1.0 = 1.45	0.60 + 1.0 = 1.60	0.75 + 1.0 = 1.75	1.13 + 1.0 = 2.13	1.50 + 1.0 = 2.50	1.88 + 1.0 = 2.88
0.5	0.05 + 0.5 = 0.55	0.10 + 0.5 = 0.60	0.20 + 0.5 = 0.70	0.25 + 0.5 = 0.75	0.30 + 1.0 = 1.30	0.40 + 1.0 = 1.40	0.50 + 1.0 = 1.50	0.60 + 1.0 = 1.60	0.80 + 1.0 = 1.80	1.00 + 1.0 = 2.00	1.50 + 1.0 = 2.50	2.00 + 1.0 = 3.00	2.50 + 1.0 = 3.50
1.0	0.08 + 0.5 = 0.58	0.15 + 0.5 = 0.65	0.30 + 0.5 = 0.80	0.38 + 0.5 = 0.88	0.45 + 1.0 = 1.45	0.60 + 1.0 = 1.60	0.75 + 1.0 = 1.75	0.90 + 1.0 = 1.90	1.20 + 1.0 = 2.20	1.50 + 1.0 = 2.50	2.25 + 1.0 = 3.25	3.00 + 1.0 = 4.00	3.75 + 1.0 = 4.75
1.5	0.10 + 0.5 = 0.60	0.20 + 0.5 = 0.70	0.40 + 0.5 = 0.90	0.50 + 0.5 = 1.00	0.60 + 1.0 = 1.60	0.80 + 1.0 = 1.80	1.00 + 1.0 = 2.00	1.20 + 1.0 = 2.20	1.60 + 1.0 = 2.60	2.00 + 1.0 = 3.00	3.00 + 1.0 = 4.00	4.00 + 1.0 = 5.00	5.00 + 1.0 = 6.00
2.0	0.13 + 0.5 = 0.63	0.25 + 0.5 = 0.75	0.50 + 0.5 = 1.00	0.63 + 0.5 = 1.13	0.75 + 1.0 = 1.75	1.00 + 1.0 = 2.00	1.25 + 1.0 = 2.25	1.50 + 1.0 = 2.50	2.00 + 1.0 = 3.00	3.50	4.75	6.00	7.25
2.5	0.15 + 0.5 = 0.65	0.30 + 0.5 = 0.80	0.60 + 0.5 = 1.10	0.75 + 0.5 = 1.25	0.90 + 1.0 = 1.90	1.20 + 1.0 = 2.20	1.50 + 1.0 = 2.50	1.80 + 1.0 = 2.80	3.40	4.00	5.50	7.00	8.50
3.0	0.18 + 0.5 = 0.68	0.35 + 0.5 = 0.85	0.70 + 0.5 = 1.20	0.88 + 0.5 = 1.38	1.05 + 1.0 = 2.05	1.40 + 1.0 = 2.40	1.75 + 1.0 = 2.75	3.10	3.80	4.50	6.25	8.00	9.75
3.5	0.20 + 0.5 = 0.70	0.40 + 0.5 = 0.90	0.80 + 0.5 = 1.30	1.00 + 0.5 = 1.50	1.20 + 1.0 = 2.20	1.60 + 1.0 = 2.60	3.00	3.40	4.20	5.00	7.00	9.00	11.00
4.0	0.23 + 0.5 = 0.73	0.45 + 0.5 = 0.95	0.90 + 0.5 = 1.40	1.13 + 0.5 = 1.63	1.35 + 1.0 = 2.35	1.80 + 1.0 = 2.80	3.25	3.70	4.60	5.50	7.75	10.00	12.25
4.5	0.25 + 0.5 = 0.75	0.50 + 0.5 = 1.00	1.00 + 0.5 = 1.50	1.25 + 0.5 = 1.75	1.50 + 1.0 = 2.50	2.00 + 1.0 = 3.00	3.50	4.00	5.00	6.00	8.50	11.00	13.50
5.0	0.28 + 0.5 = 0.78	0.60 + 0.5 = 1.10	1.10 + 0.5 = 1.60	1.38 + 0.5 = 1.88	1.65 + 1.0 = 2.65	3.20	3.75	4.30	5.40	6.50	9.25	12.00	14.75

Figure 2-10 Combinations of flood depth and velocity that cause danger to people (Source: DEFRA/Environment Agency research on Flood Risks to People - FD2320/TR2)

Table 2-5: Derivation of Hazard Rating category

Degree of Flood Hazard	Hazard Rating (HR)		Description
Low	<0.75	Caution	Flood zone with shallow flowing water or deep standing water
Moderate	0.75b – 1.25	Dangerous for some (i.e. children)	Danger: Flood zone with deep or fast flowing water
Significant	1.25 -2.5	Dangerous for most people	Danger: Flood zone with deep fast flowing water
Extreme	>2.5	Dangerous for all	Extreme danger: Flood zone with deep fast flowing water

2.7 Ordinary Watercourse Flooding

2.7.1 Description

All watercourses in England and Wales are classified as either 'Main Rivers' or 'Ordinary Watercourses'. The difference between the two classifications is based largely on the perceived importance of a watercourse, and in particular it's potential to cause significant and widespread flooding. However, this is not to say watercourses classified as Ordinary Watercourses cannot cause localised flooding. The Water Resources Act (1991) defines a 'Main River' as "a watercourse shown as such on a Main River Map". The Environment Agency keep and maintain information on the spatial extent of the Main River designations. The Floods and Water Management Act (2010) defines any watercourse that is not a Main River an Ordinary Watercourse – including ditches, dykes, rivers, streams and drains (as in 'land drains') but not public sewers.

The Environment Agency have duties and powers in relation to Main Rivers. Local Authorities, or in some cases Internal Drainage Boards, have powers and duties in relation to Ordinary Watercourses.

Flooding from Ordinary Watercourses occurs when water levels in the stream or river channel rise beyond the capacity of the channel, causing floodwater to spill over the banks of the watercourse and onto the adjacent land. The main reasons for water levels rising in ordinary watercourses are:

- Intense or prolonged rainfall causing rapid run-off increasing flow in watercourses, exceeding the capacity of the channel. This can be exacerbated by wet antecedent (the preceding time period) conditions and where there are significant contributions of groundwater;
- Constrictions/obstructions within the channel causing flood water to backup;
- Blockage/obstructions of structures causing flood water to backup and overtop the banks; and
- High water levels in rivers preventing discharge at the outlet of the Ordinary Watercourse (often into a Main River).

Table 1-1 provides a summary of the Main Rivers located in the Borough. The EA Main River dataset should be utilised by the NCC and Borough Council to determine which watercourses they are required to maintain and manage under the FWMA. This will also require consultation with the IDBs to ensure that all Ordinary Watercourse are maintained within the Borough.

2.7.2 Impacts of Flooding from Ordinary Watercourse

The consequence of ordinary watercourse flooding is dependent upon the degree of hazard generated by the flood water (as specified within the Defra/Environment Agency research on Flood Risks to People - FD2321/TR2) and what the receptor is (e.g. the consequence of a hospital flooding is greater than that of a commercial retailer). The hazard posed by flood water is related to the depth and velocity of water, which, in Ordinary Watercourses, depends on:

- Constrictions in the channel causing flood water to backup;
- The magnitude of flood flows;
- The size, shape and slope of the channel;
- The width and roughness of the adjacent floodplain; and
- The types of structures that span the channel.

The hazard presented by floodwater is proportional to the depth of water, the velocity of flow and the speed of onset of flooding. Hazardous flows can pose a significant risk to exposed people, property and infrastructure.

Whilst low hazard flows are less of a risk to life (shallow, slow moving/still water), they can disrupt communities, require significant post-flood clean-up and can cause costly and possibly permanent structural damage to property.

2.7.3 Methodology for Assessing Ordinary Watercourses

Ordinary watercourses have been included in the pluvial flood modelling. Watercourses have been defined by digitising 'breaklines' along the centre line of each watercourse. 'Breaklines' are used primarily to raise the elevation of the watercourse to the level of the surrounding banks to represent a "bank full" scenario. Elevations of watercourses have been determined from LiDAR.

Structures along the watercourse have been modelled as either 1D or 2D elements, depending on the length and location of the structure. The dimensions of structures have been determined from asset information obtained in the data collection stage where available or inferred from site visits or LiDAR data.

The assessment of flood risk from ordinary watercourses has been based on outputs from the pluvial modelling process described earlier in this Section, and presented in Appendix C.

2.7.4 Uncertainties and Limitations – Ordinary Watercourse Modelling

As with any hydraulic model, these models have been based on a number of assumptions which may introduce uncertainties into the assessment of risk. The assumptions within the models should be noted and understood such that informed decisions can be made when using model results.

In relation to ordinary watercourses, the limits of the modelling include (but are not limited to):

- Modelling of structures has not been based on detailed survey data;
- The watercourses are assumed to be bank full at the start of the rainfall event, hence river flows and channel capacities have not been taken into account – more detailed assessment of larger ordinary watercourses (e.g. Gaywood River, Middleton Stop Drain etc) may assist in understanding the risk from this source and should be undertaken at a later date; and
- Only one storm duration was considered for this study.

Taking these uncertainties and constraints into consideration, the estimation of risk of flooding from rivers presented in this report is considered robust for the level of assessment required in the SWMP.

2.8 Groundwater Flooding

2.8.1 Description

Groundwater flooding is water originating from sub-surface permeable strata which emerges from the ground, either at a specific point (such as a spring) or over a wide diffuse location, and inundates low lying areas. A groundwater flood event results from a rise in groundwater level sufficient for the water table to intersect the ground surface and inundate low lying land. The actual flooding can occur some distance from the emergence zone, with increased flows in local streams resulting in flooding at downstream pinch points. This can make groundwater flooding difficult to categorise. Flooding from groundwater tends to be long in duration, developing over weeks or months and continuing for days or weeks.

There are many mechanisms associated with groundwater flooding, which are linked to high groundwater levels, and can be broadly classified as:

- Direct contribution to channel flow;
- Springs erupting at the surface;
- Inundation of drainage infrastructure; and
- Inundation of low-lying property (basements).

2.8.2 Impacts of Groundwater Flooding

The main impacts of groundwater flooding are:

- Flooding of basements of buildings below ground level – in the mildest case this may involve seepage of small volumes of water through walls, temporary loss of services etc. In more extreme cases larger volumes may lead to the catastrophic loss of stored items and failure of structural integrity;
- Overflowing of sewers and drains – surcharging of drainage networks can lead to overland flows causing significant but localised damage to property. Sewer surcharging can lead to inundation of property by polluted water. Note: it is complex to separate this flooding from other sources, notably surface water or sewer flooding;
- Flooding of buried services or other assets below ground level – prolonged inundation of buried services can lead to interruption and disruption of supply;
- Inundation of roads, commercial, residential and amenity areas – inundation of grassed areas can be inconvenient, however the inundation of hard-standing areas can lead to structural damage and the disruption of commercial activity. Inundation of agricultural land for long durations can have financial consequences; and
- Flooding of ground floors of buildings above ground level – can be disruptive, and may result in structural damage. The long duration of flooding can outweigh the lead time which would otherwise reduce the overall level of damages.

In general terms groundwater flooding rarely poses a risk to life. Figure 2-11 shows the EA Areas Susceptible to GrounWater Flooding maps.

2.8.3 Groundwater Flooding Risk Assessment

The data sources listed below have been reviewed to produce an overall interpretation of groundwater flood risk in the study area.

- Areas Susceptible to Groundwater Flooding (EA, 2011); and
- EA historic records.

While only two data sources above are directly related to groundwater flood risk, the other studies (SFRA, WSC) were reviewed to gain an understanding of groundwater behaviour in the study area.

The information sources listed above were reviewed as part of this study. Table 2-6 summarises the content of each source and how it has been used within the risk assessment.

Table 2-6: Review of Available Groundwater Information

Source	Summary	Risk Assessment Application
EA Areas Susceptible to Groundwater Flooding	This data has used the top two susceptibility bands of the British Geological Society (BGS) 1:50,000 Groundwater Flood Susceptibility Map and thus covers consolidated aquifers (chalk, sandstone etc., termed 'clearwater' in the data attributes) and superficial deposits. It does not take account of the chance of flooding from groundwater rebound. It shows the proportion of each 1km grid square where geological and hydrogeological conditions show that groundwater might emerge	This was identified as the best available dataset for assessment of potential groundwater flood risk and used to classify risk to settlements based on the following criteria. (green) >25% risk = low (yellow) (≥25%<50%) =moderate (pink) ≥ 50% <75% = high (red) <75% =very high
EA historic records	This database only provided only two incident record for the study area.	Assisted in verifying the flood risk identified in the AStGWF maps

The basis for the groundwater flood risk assessment for this study is predominantly the EA Areas Susceptible to Groundwater Flooding map. This map uses underlying geological information to infer groundwater flood susceptibility.

Figures 4.0 - 4.5 (within Appendix C) identify the groundwater flood risk within the Borough based on the BGS Susceptibility to Groundwater Flood Map. Please note that this data set was unavailable when the original site assessments were undertaken and should be reviewed in conjunction with any groundwater flooding commentary, as it provides a greater level of detail.

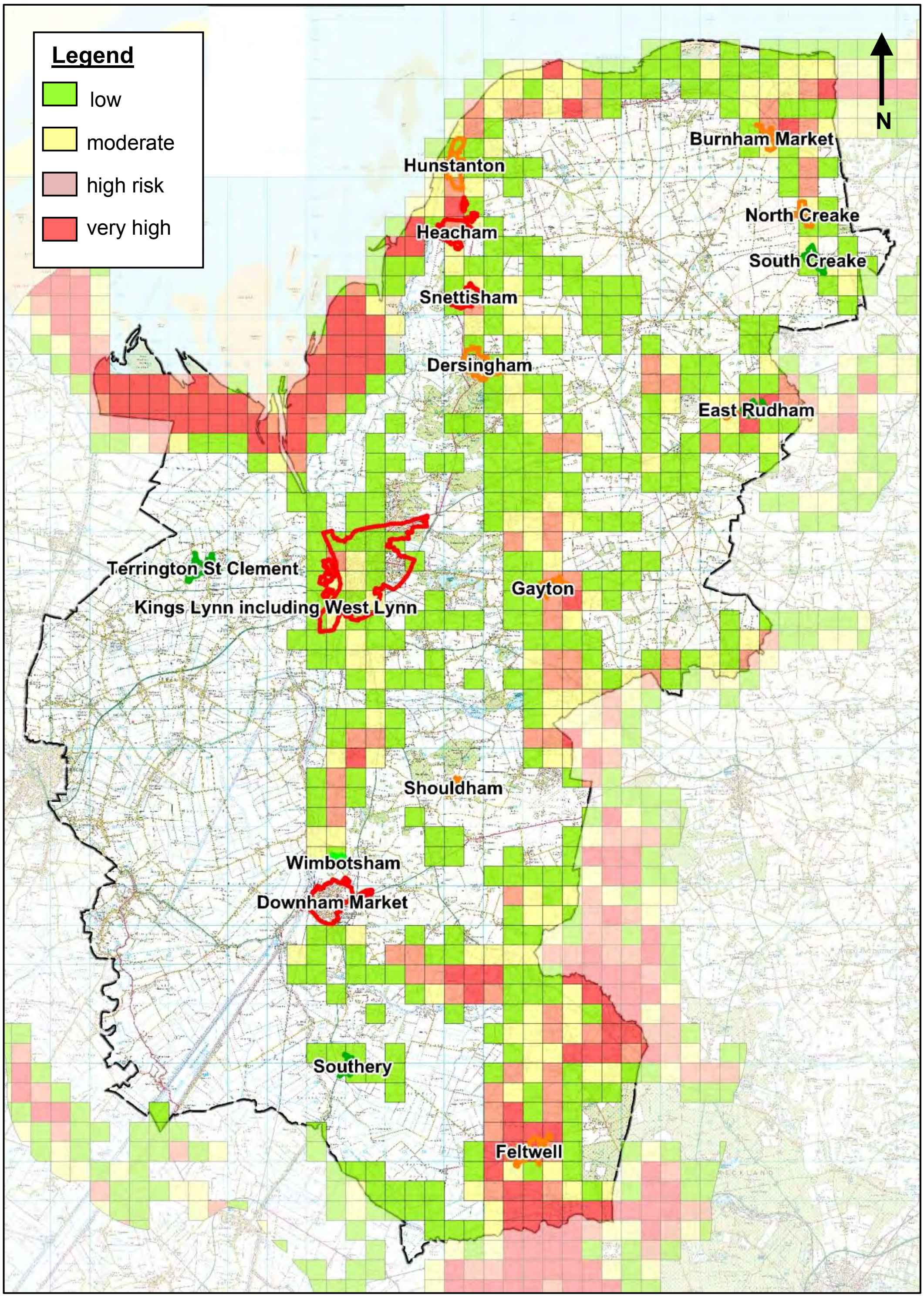


Figure 2-11 Environment Agency Areas Susceptible to Groundwater Flooding Map

2.8.4 Geology

A geological map for the study area is provided in Appendix C, reproduced from the British Geological Survey (BGS) 1:50,000 scale geological series.

The bedrock geology of the Borough is primarily split between clay and chalk, with large areas of Kimmeridge Clay in the west and the Upper Chalk Formation in the east. Intermediate areas primarily comprise alluvium, sand and gravel. The nature of the underlying geology affects the potential for groundwater flooding as well as the surface water drainage mechanisms and possible mitigation actions. Chalk sub-strata, indicating the presence of groundwater, can be linked to a heightened risk of groundwater flooding but also enables the use of infiltrating sustainable drainage (SuDS) features to reduce runoff volumes from urban areas. Conversely, clay substrata inhibits the use of infiltrating SuDS features but also indicates a lower risk of groundwater flooding due to the inherent absence of large bodies of groundwater.

Table 2-7 Geology within the Assessed Settlements

SWMP Settlement	Primary Bedrock Geology	Primary Superficial Geology
Hunstanton	Middle and Lower Chalk Formation and Carstone Formation	Largely unknown, small areas of Till
Heacham	Snettisham Clay Formation	Largely unknown, small areas of Till
Snettisham	Dersingham Formation (Sandstone) and Sandringham Sand Formation, Roxham Member and Runcton Member (Undifferentiated)	Unknown
Dersingham	Dersingham Formation (Sandstone), Sandringham Sand Formation, Roxham Member and Runcton Member (Undifferentiated)	Unknown
Burnham Market	Upper Chalk Formation	River Terrace Deposits (Undifferentiated)
North Creake	Upper Chalk Formation	Till and Glacial Sand & Gravel
South Creake	Upper Chalk Formation	Glacial Sand & Gravel
East Rudham	Upper Chalk Formation	Unknown
West Rudham	Upper Chalk Formation	Unknown
Terrington St. Clement	Kimmeridge Clay formation	Alluvium
King's Lynn	Kimmeridge Clay formation and Sandringham Sand Formation	Alluvium, Till, Glacial Sand & Gravel, and Peat
Gayton	Lower Chalk Formation and Gault Formation (Clay)	Unknown
Shouldham	Gault Formation (Clay)	Unknown
Wimbotsham	Sandringham Sand Formation and Carston Formation	Largely unknown, small areas of River Terrace Deposits (Undifferentiated)
Downham Market	Sandringham Sand Formation and Carston Formation	Largely unknown, small areas of Till
Southery	Sandringham Sand Formation	Largely unknown, with and area of Peat
Feltwell	Lower Chalk formation	Unknown

Groundwater levels rise and fall in response to rainfall patterns and distribution, with a time scale of months rather than days. The significance of this rise and fall for flooding, depends largely on the type of ground it occurs in, i.e. how permeable to water the ground is, and whether the water level comes close to or meets the ground surface.

Groundwater flooding is often highly localised and complex. Large areas within the study area are underlain by permeable substrate and thereby have the potential to store groundwater. Under some circumstances groundwater levels can rise and cause flooding problems in subsurface structures or at the ground surface. The mapping technique adopted by the EA aims to identify only those areas in which there is the greatest potential for this to happen.

There is currently no research specifically considering the impact of climate change on groundwater flooding. The mechanisms of flooding from aquifers are unlikely to be affected by climate change, however if winter rainfall becomes more frequent and heavier, groundwater levels may increase. Higher winter recharge may however be balanced by lower recharge during the predicted hotter and drier summers.

2.8.5 Groundwater Flooding Management

Management is highly dependent upon the characteristics of the specific situation. The costs associated with the management of groundwater flooding are highly variable. The implications of groundwater flooding should be considered and managed through development control and building design. Possible responses include:

- Raising property ground or floor levels or avoiding the building of basements in areas considered to be at risk of groundwater flooding.
- Provide local protection for specific problem areas such as flood-proofing properties (such as tanking, sealing of building basements, raising the electrical sockets/TV points etc).
- Replacement and renewal of leaking sewers, drains and water supply reservoirs. Water companies have a programme to address leakage from infrastructure, so there is clear ownership of the potential source.
- Major ground works (such as construction of new or enlarged watercourses) and improvements to the existing surface water drainage network to improve conveyance of floodwater from surface water of fluvial events through and away from areas prone to groundwater flooding.

Most options involve the management of groundwater levels. It is important to assess the impact of managing groundwater with regard to water resources, and environmental designations. Likewise, placing a barrier to groundwater movement can shift groundwater flooding from one location to another. The appropriateness of infiltration based drainage techniques should also be questioned in areas where groundwater levels are high or where source protection zones are close by.

2.8.6 Uncertainties and Limitations – Groundwater Flooding

Within the areas delineated, the local rise of groundwater will be heavily controlled by local geological features and artificial influences (e.g. structures or conduits) which cannot currently be represented. This localised nature of groundwater flooding compared with, say, fluvial flooding suggests that interpretation of the map should similarly be different. The map shows the area within which groundwater has the potential to emerge but it is unlikely to emerge uniformly or in sufficient volume to fill the topography to the implied level. Instead, groundwater emerging at the surface may simply runoff to pond in lower areas.

Locations shown to be at risk of surface water flooding are also likely to be most at risk of runoff/ponding caused by groundwater flooding. Therefore the susceptibility map should not be used as a "flood outline" within which properties at risk can be counted. Rather, it is provided, in conjunction with the surface water mapping, to identify those areas where groundwater may emerge and what the major water flow pathways would be in that event.

It should be noted that this assessment is broad scale and does not provide a detailed analysis of groundwater; it only aims to provide an indication of where more detailed consideration of the risks may be required.

The causes of groundwater flooding are generally understood. However, groundwater flooding is dependent on local variations in topography, geology and soils. It is difficult to predict the actual location, timing and extent of groundwater flooding without comprehensive datasets.

There is a lack of reliable measured datasets to undertake flood frequency analysis on groundwater flooding and even with datasets this analysis is complicated due to the non-independence of groundwater level data. Studies therefore tend to analyse historic flooding which means that it is difficult to assign a level of certainty.

The impact of climate change on groundwater levels is highly uncertain. More winter rainfall may increase the frequency of groundwater flooding incidents, but drier summers and lower recharge of aquifers may counteract this effect.

Source protection zones (SPZs) should be considered when applying mitigation measures, such as SuDS, which have the potential to contaminate the underlying aquifer if this is not considered adequately in the design. Generally, it will not be acceptable to use infiltrating SuDS in an SPZ 1 if the drainage catchment comprises trafficked surfaces or other areas with a high risk of contamination. SPZs within the SWMP defined study areas, are shown in Appendix C.

2.8.7 Infiltration SuDS

Improper use of infiltration SuDS could lead to contamination of the superficial deposit or bedrock aquifers, leading to deterioration in aquifer quality status or groundwater flooding / drainage issues. However, correct use of infiltration SuDS is likely to help improve aquifer quality status and reduce overall flood risk.

Environment Agency guidance on infiltration SuDS is available on their website at: http://www.environment-agency.gov.uk/business/sectors/36998.aspx. This should be considered by developers and their contractors, and by the Councils when approving or rejecting planning applications.

The areas that may be suitable for infiltration SuDS exist where there is a combination of high ground and permeable geology. However, consideration should be given to the impact of increased infiltration SuDS on properties further down gradient. An increase in infiltration and groundwater recharge will lead to an increase in groundwater levels, thereby increasing the susceptibility to groundwater flooding at a down gradient location. This type of analysis is beyond the scope of the current report, but it could be as significant problem where there is potential for perched water tables to develop.

Restrictions on the use of infiltration SuDS apply to those areas within Source Protection Zones (SPZ). Developers must ensure that their proposed drainage designs comply with the available Environment Agency guidance. It is also recommended that developers consider the potential for infiltration SuDS to cause the development of solution features within the Chalk, leading to potential subsidence issues.

2.9 Sewer Flooding

2.9.1 Description

Flooding which occurs when the capacity of the underground drainage network is exceeded, resulting in the surcharging of water into the nearby environment (or within internal and external building drainage networks) or when there is an infrastructure failure. The discharge of the drainage network into waterways and rivers can also be affected if high water levels in receiving waters obstruct the drainage network outfalls. In the study area, the sewer network varies from a largely separated foul and surface water system to whole settlements relying on a combined system.

2.9.2 Causes of sewer flooding

The main causes of sewer flooding are:

- Lack of capacity in the sewer drainage networks due to original under-design – this is a result of the original design criteria requiring a reduced standard of protection which was acceptable at the time of construction;
- Lack of capacity in sewer drainage networks due to an increase in flow (such as climate change and/or new developments connecting to the network);
- Exceeded capacity in sewer drainage networks due to events larger than the system designed event;
- Loss of capacity in sewer drainage networks when a watercourse has been fully culverted and diverted or incorporated into the formal drainage network (lost watercourses);
- Lack of maintenance or failure of sewer networks which leads to a reduction in capacity and can sometimes lead to total sewer blockage;
- Failure of sewerage infrastructure such as pump stations or flap valves leading to surface water or combined foul/surface water flooding;
- Additional paved or roof areas i.e. paved driveways and conservatories connected onto existing network without any control;
- Lack of gully maintenance restricting transfer of flows into the drainage network;
- Groundwater infiltration into poorly maintained or damaged pipe networks; and
- Restricted outflow from the sewer systems due to high water or tide levels in receiving watercourses ('tide locking').

2.9.3 Impacts of Sewer Flooding

The impact of sewer flooding is usually confined to relatively small localised areas but, because flooding is associated with blockage or failure of the sewer network, flooding can be rapid and unpredictable. Flood waters from this source are also often contaminated with raw sewage and pose a health risk. The spreading of illness and disease can be a concern to the local population if this form of flooding occurs on a regular basis.

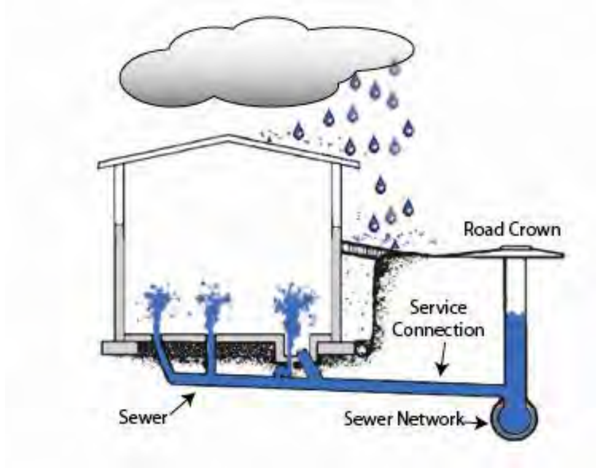


Figure 2-12 Surcharging of the sewer system within a road (left) and internally within a property (right)

Drainage systems often rely on gravity assisted dendritic systems, which convey water in trunk sewers located at the lower end of the catchment. Failure of these trunk sewers can have serious consequences, which are often exacerbated by topography, as water from surcharged manholes will flow into low-lying urban areas.

The diversion of "natural" watercourses into culverted or piped structures is a historic feature of the study area drainage network. Where it has occurred, deliberately or accidentally it can result in a reduced available capacity in the network during rainfall events when the sewers drain the watercourses catchment as well as the formal network. Excess water from these watercourses may flow along unexpected routes at the surface (usually dry and often developed) as its original channel is no longer present and the formal drainage system cannot absorb it.

In order to clearly identify problems and solutions, it is important to first outline the responsibilities of different organisations with respect to drainage infrastructure. The responsible parties are primarily the Highways Authority and Anglian Water.

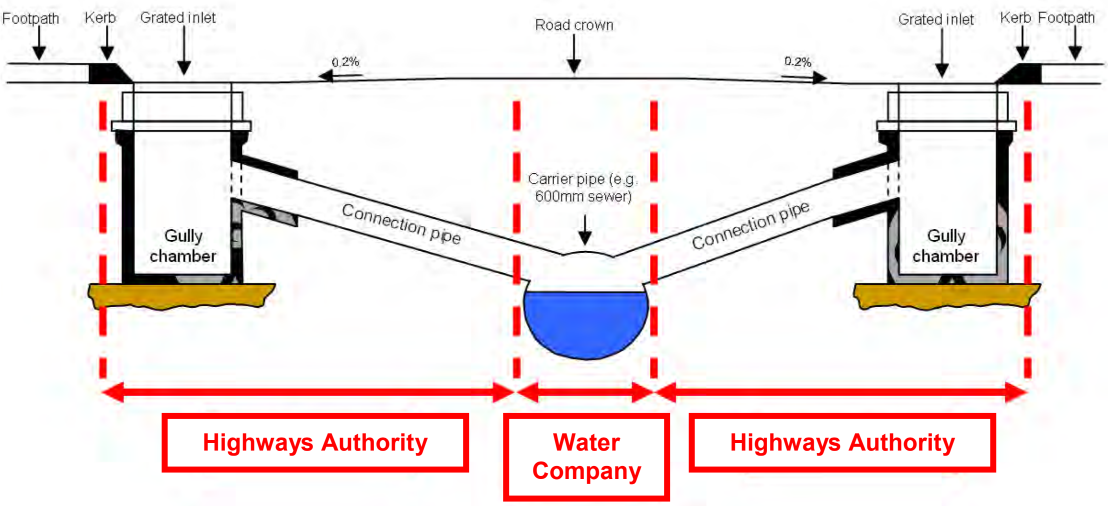


Figure 2-13 Surface water sewer responsibility

As illustrated in Figure 2-13, Norfolk County Council, as the Highways Authority, is responsible for maintaining an effective highway drainage system including kerbs, road gullies and the pipes which connect the gullies to the trunk sewers and soakaways. Norfolk County Council is also the Highways Authority for all roads except trunk roads. The sewerage undertaker, in this case Anglian Water, is responsible for maintaining the trunk sewers.

New drainage networks are designed as separate foul and Surface water sewers. New surface water systems are typically designed to accommodate 1 in 30 year storm events. New foul sewers are designed for the population which to be served, with allowance for infiltration. Anglian Water have indicated that only existing foul/combined systems that flood during storm conditions will be upgraded to accommodate 1 in 30 year storm returns for internal flooding and 1 in 20 for external flooding. Therefore, rainfall events with a return period or frequency greater than 1 in 30 years would be expected to result in surcharging of some of the sewer system.

The King's Lynn and West Norfolk Water Cycle Study Stage 2 (Entec, 2011) highlighted a number of issues with the capacity of the sewer network in the Borough, indicating a significant risk from sewer flooding. Anglian Water are currently working towards a long term development strategy in order to provide sufficient capacity to account for new proposed developments across the Borough.

The data provided by Anglian Water, for use in this SWMP, identifies some historic records of sewer flooding within the Borough. The Flooded Data spreadsheet indicated that the majority of sewer flooding incidents were located in King's Lynn (16 records), Downham Market (12 records) and Heacham (10 records)[3].

2.9.4 Drainage Network

A number of different data sources were used to obtain a detailed understanding of the sewer network across King's Lynn and West Norfolk, primarily through consultation with Anglian Water and the IDB's. Anglian Water is keen to work with King's Lynn and West Norfolk Council and the LLFA (Norfolk County Council), in order to mitigate flood risk issues in an integrated manner.

Anglian Water provided details of the infrastructure network including sewers, manholes, pumping stations and outfalls in GIS format. This information was overlaid onto the pluvial modelling outputs to assist with the identification of high risk areas by reviewing the type of pipe network (combined, foul, separated) to determine if ponding could exist due to the existing capacity of the network (pipe size, outfall location).

2.9.5 Methodology for Drainage Network Modelling

Consultation with Anglian Water and the IDB's determined that the sewer system within King's Lynn should be assumed as being 'tide locked' with no representation of a drainage network, whilst Snettisham, Heacham and Downham Market would be run with a limited capacity (3mm/hr) to reflect minor storage within the network (refer to assumption discussed in Section 2.6.7). This was represented in the surface water modelling by removing 3mm/hr from the rainfall totals on impermeable landuses, for the duration of the model run.

The sewer system was not modelled explicitly, hence interaction between the sewer system and surface water modelling is not investigated. This was beyond the scope of the study but, in specific areas where the sewer network has been identified to be of particular relevance to flood risk, more detailed integrated modelling may be required at a later date to determine if improving the capacity and conveyance within the network could reduce the risk of surface water flooding.

[3] Flooding Register Tab from the Flooding Data edited.xls provided on the 7th November 2011

2.9.6 Uncertainties in Flood Risk Assessment – Sewer Flooding

Assessing the risk of sewer flooding over a wide area is limited by the lack of data and the quality of data that is available. Furthermore, flood events may be a combination of surface water, groundwater and sewer flooding.

An integrated modelling approach is required to assess and identify the potential for sewer flooding but these models are complex and require detailed information. Obtaining this information can be problematic as datasets held by stakeholders are often confidential, contain varying levels of detail and may not be complete. Sewer flood models require a greater number of parameters to be input and this increases the uncertainty of the model predictions.

Existing sewer models are generally not capable of predicting flood routing (flood pathways and receptors) in the above ground network of flow routes (for example streams, dry valleys, and highways).

Use of historic data to estimate the probability of sewer flooding is the most practical approach; however it does not take account of possible future changes due to climate change or future development. Nor does it account for improvements to the network, including clearance of blockages, which may have occurred.

2.10 Main River Fluvial and Tidal Flooding

Interactions between surface water and fluvial flooding are generally a result of watercourses unable to receive and convey excess surface water runoff. Where the watercourse in question is defended, surface water can pond behind defences. This may be exacerbated in situations where high water levels in the watercourse prevent discharge via flap valves through defence walls.

Main rivers have been considered in the surface water modelling by assuming a 'bank full' condition, in the same way that ordinary watercourses have been modelled. Structures such as weirs, locks and gates along watercourses have not been explicitly modelled.

Historically, a network of flood defences has been constructed to reduce flood risk within the Borough, and large drainage features are used to manage discharge during flood events. Whilst managing flood risk over large areas of the Borough, as shown in Figure 2-14, this flood defence infrastructure does increase the residual risk of flooding in these areas due to the possibility of its failure (and can also influence flooding on the upstream side as a result of the unnatural obstruction to surface water flows). There are two primary modes of defence failure; overtopping and breach. The latter is commonly far more destructive than the former and has been the focus of numerous modelling exercises within the Borough, refer to the SFRA for further information.

The residual risk of failure is exacerbated by the fact that a number of the watercourses within the Borough are embanked and thus have water levels which are commonly above the surrounding topography. Surface water drainage within many catchments is dependent upon the work of the Internal Drainage Boards, some of which rely on pumping stations to raise runoff into the embanked watercourses.

Figure 2-14 displays the Environment Agency's Flood Risk Zones and identifies the areas benefiting from defences. The outlines indicate that the risk of fluvial flooding from Main Rivers and Tidal sources is largely concentrated around the low lying areas of the Borough (The Fens) and the settlements located in close proximity to the coast and river(s).

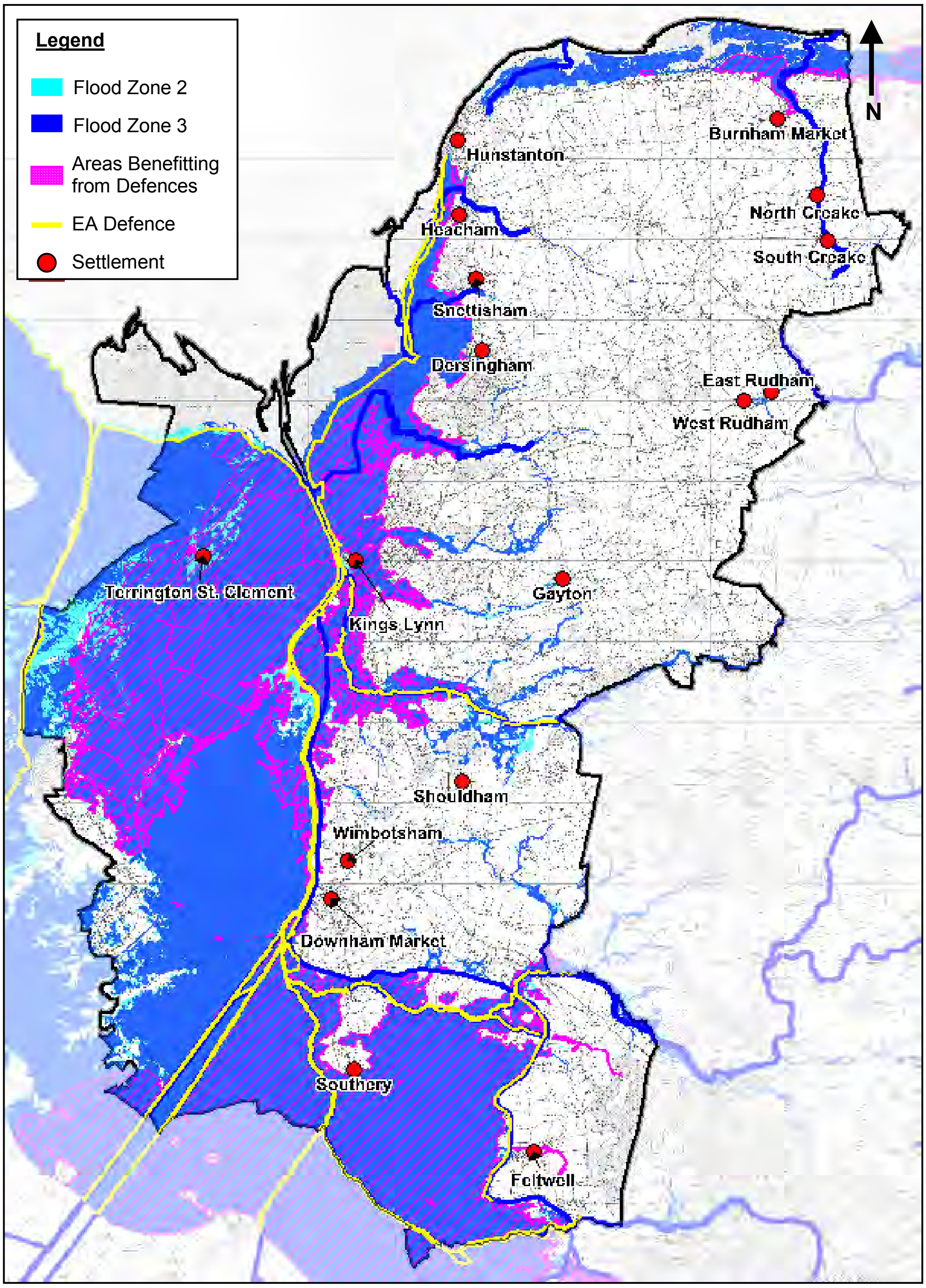


Figure 2-14 Flood Zones and Defence Locations within the Borough

Please note that the effects of main river flooding have not been assessed as part of this study; more information can be found in the CFMP and SFRA documents. Further information on fluvial (Main River) and tidal flooding can be found in the following SFRA documents:

- Bullen Consultants (2005) Level 1 Strategic Flood Risk Assessment;
- Faber Maunsell (2008) Revised Level 1 Strategic Flood Risk Assessment; and
- Entec (2010) Level 1 Strategic Flood Risk Assessment Addendum.

3 Identification of Flood Risk Areas

3.1 Overview

The purpose of the intermediate risk assessment is to identify those parts of the study area that are likely to require more detailed assessment to gain an improved understanding of the causes and consequences of surface water flooding. The intermediate assessment was used to identify areas where the flood risk is considered to be most severe; these areas are identified as Critical Drainage Areas (CDAs). The working definition of a CDA in this context has been agreed as:

> *'a discrete geographic area (usually a hydrological catchment) where multiple or interlinked sources of flood risk cause flooding during a severe rainfall event thereby affecting people, property or local infrastructure.'*

The CDA comprises the upstream 'contributing' catchment, the influencing drainage catchments, surface water catchments and, where appropriate, a downstream area if this can have an influence on CDA. They are typically located within Flood Zone 1 but should not be excluded from other Flood Zones if a clear surface water (outside of other influences) flood risk is present. In spatially defining a CDA, the following should be taken into account:

- **Flood depth and extent** – CDAs should be defined by looking at areas within the study area which are predicted to suffer from deep levels of surface water flooding;
- **Surface water flow paths and velocities** – Overland flow paths and velocities should also be considered when defining CDAs;
- **Flood hazard** – a function of flood depth and velocity, the flood hazard ratings across the modelled settlements should also be used to define CDAs;
- **Potential impact on people, properties and critical infrastructure** – including residential properties, main roads (access to hospitals or evacuation routes), rail routes, rail stations, hospitals and schools;
- **Groundwater flood risk** – based on groundwater assessment and EA AStGWF dataset identifying areas most susceptible to groundwater flooding;
- **Sewer capacity issues** – based on sewer flooding assessment and information obtained from Anglian Water and their sewer modelling consultants;
- **Significant underground linkages** – including underpasses, tunnels, large diameter pipelines (surface water, sewer or combined) or culverted rivers;
- **Cross boundary linkages** – CDAs should not be curtailed by political or administrative boundaries;
- **Definition of area** – including the hydraulic catchment contributing to the CDA and the area available for flood mitigation options; and
- **Source, pathway and receptor** – the source, pathway and receptor of the main flooding mechanisms should be included within the CDA.

Where CDAs are difficult to identify, it is recommended that Local Flood Risk Zones (LFRZ) are identified to enable further investigation to determine if they are part of a wider CDA. A LFRZ is defined as discrete areas of flooding that do not exceed the national criteria for a 'Flood Risk Area' but still affect properties, businesses or infrastructure. A LFRZ is defined as the actual spatial extent of predicted flooding in a single location.

Based on the above criteria, and identified flood risk within the study area, it has currently been concluded that there are no CDAs within the study area and that the focus of the SWMP is to identify LFRZs which are recommended for further investigation within the accompanying Action Plan (Section 7.1).

3.2 King's Lynn LFRZs

The settlement of King's Lynn is located within the centre of the Borough on the eastern bank of the River Great Ouse. The results of the intermediate level surface water modelling combined with site visits (and a review of historic flood records) indicate that there is a moderate to high risk of surface water flooding within the settlement from both overland flow and existing watercourses. This assessment also includes the area of South Wootton. There is some correlation between information on past flooding in the settlement and the modelling outputs which provides confidence in the accuracy of the model outputs. Figure 3-2 illustrates the LFRZs within the settlement along with the predicted flood extent during a 1 in 100 year probability event (1% AEP).

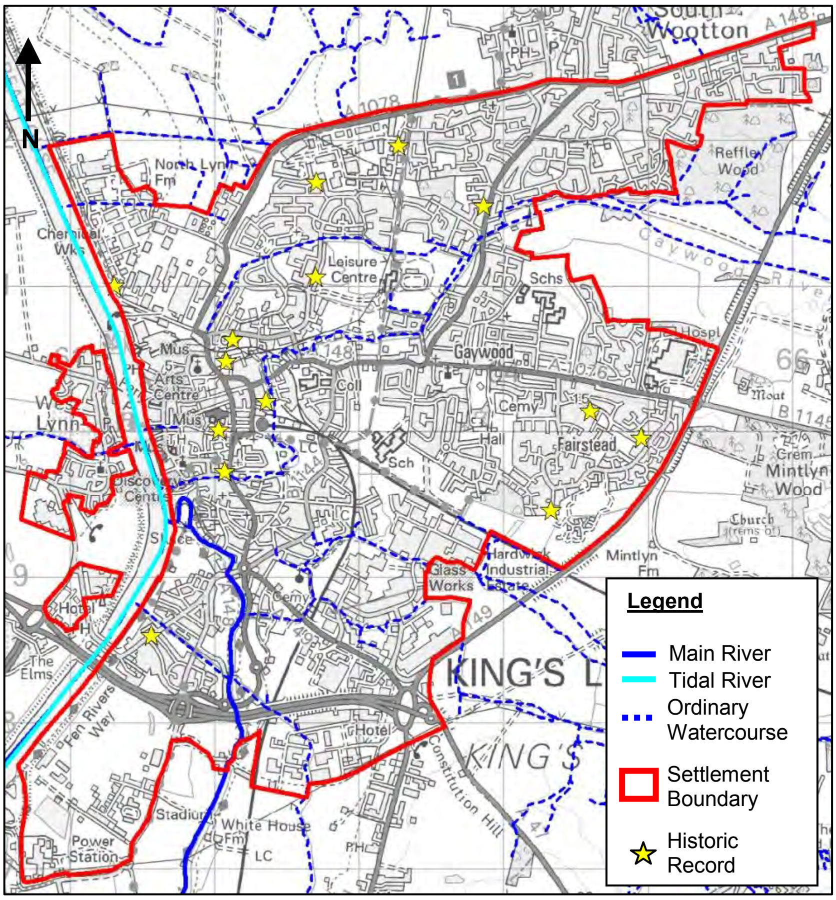


Figure 3-1 Historic Records within King's Lynn

Over 10 historic records have been identified within the settlement, with the majority of these occuring near the settlement centre (refer to Figure 3-1, left).

King's Lynn utilises a separated foul and surface water drainage network. These in turn either discharge into the watercourses that flow through the settlement or utilise the extensive pumping regime located within the settlement. Surface water pipe sizes vary considerably throughout the settlement with 150mm pipes located in the upper catchments and in excess of 1.7m (average sizes appear to be 225mm-450mm) in lower areas.

The EA Areas Susceptible to Groundwater Flooding map indicates that the upper catchment of the settlement is considered at a less than low risk of groundwater emergence whilst the centre of the settlement (near the watercourses) is at a moderate risk of groundwater emergence. The highest risk is located in the northeast of the settlement, where the risk is estimated to be high.

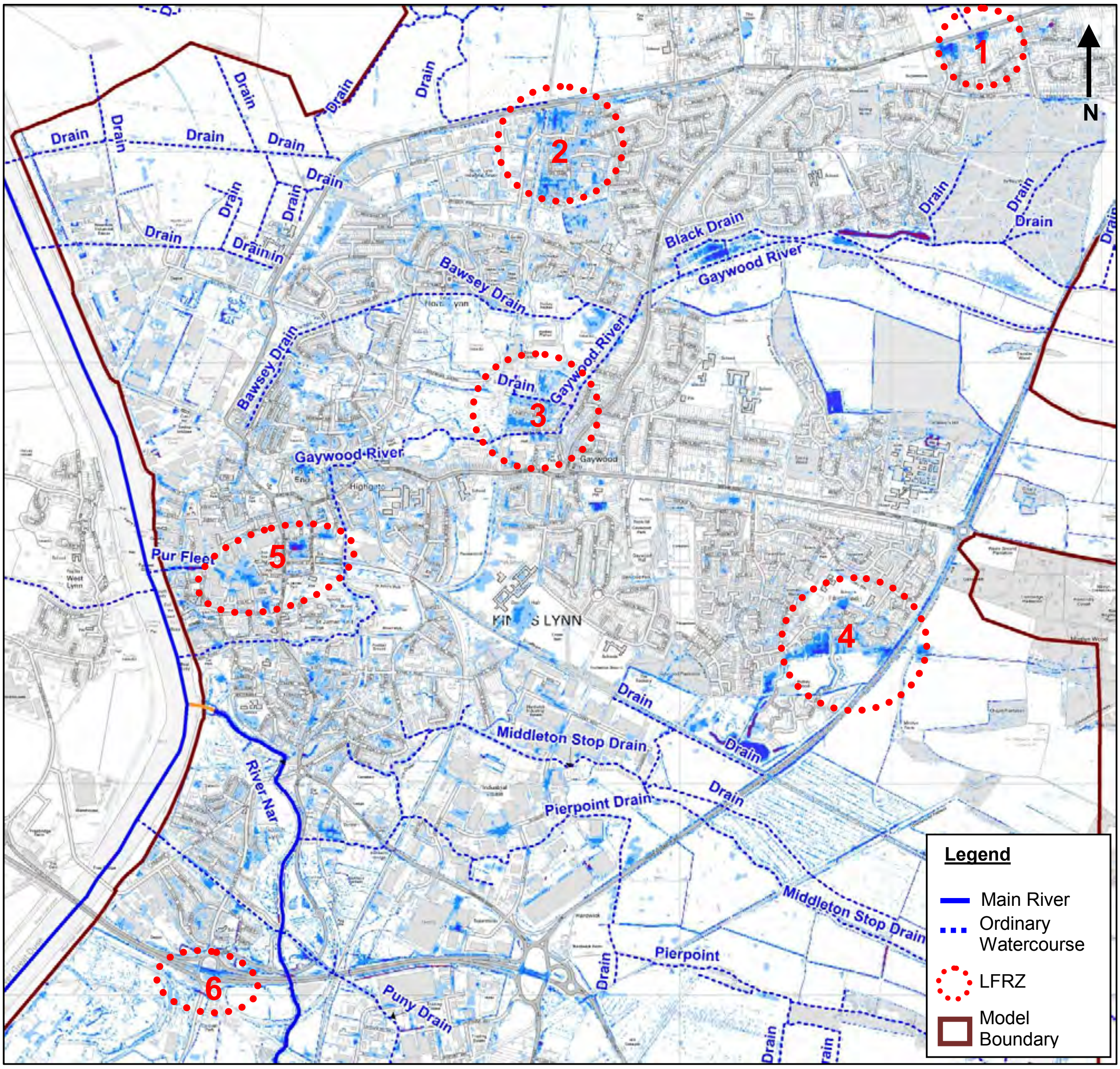
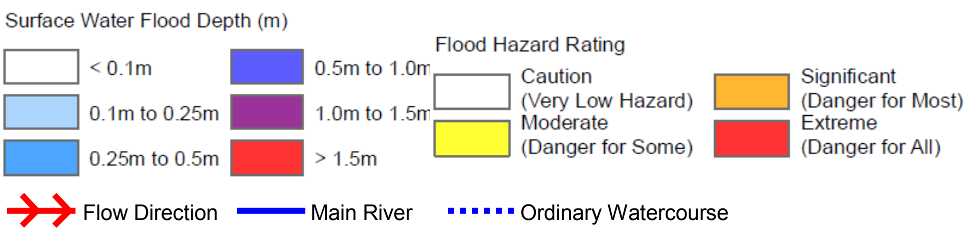


Figure 3-2 Local Flood Risk Zones within King's Lynn

The following legend applies to all of the LFRZ summaries.



LFRZ 1 – Green Lane, South Wootton

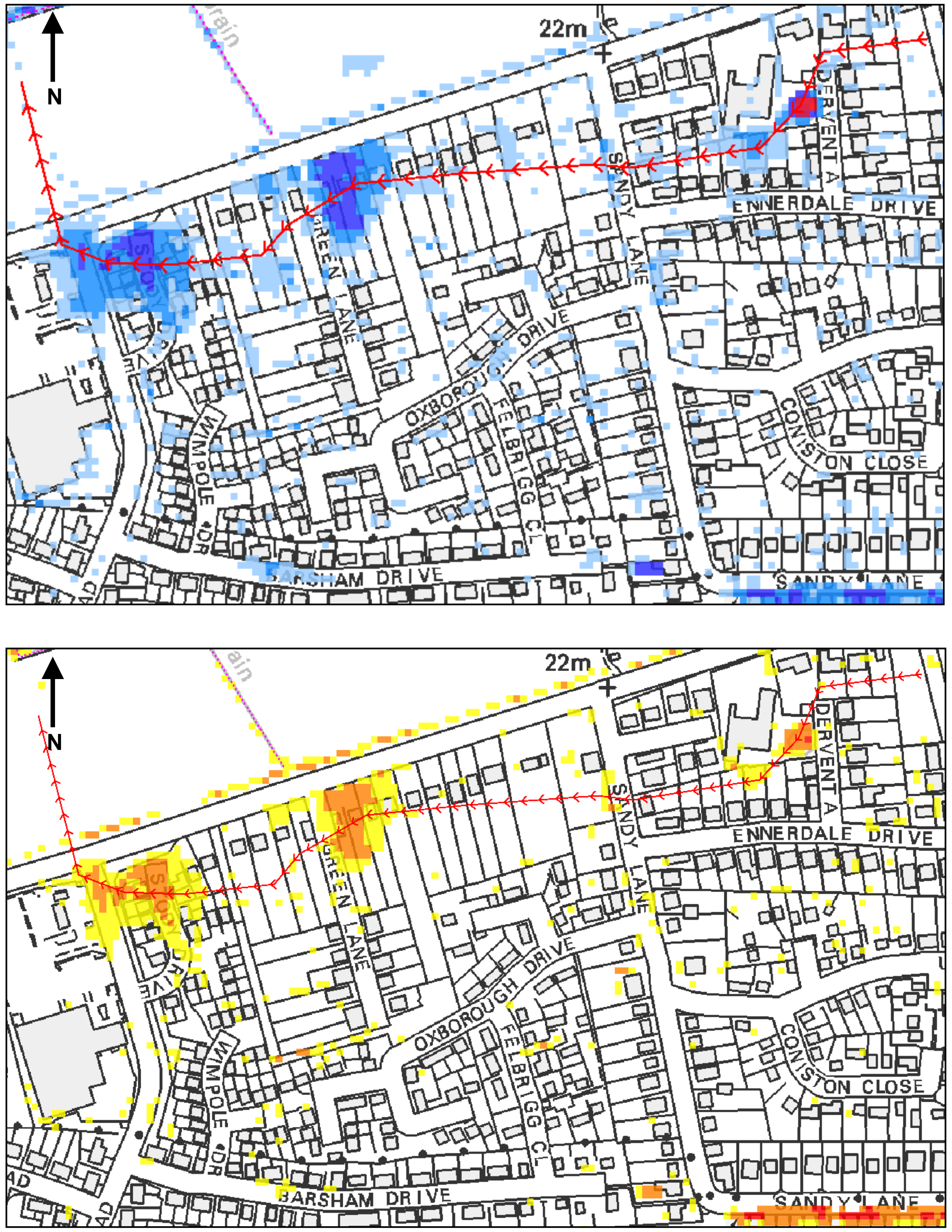


Figure 3-3 Flood Depth and Hazard for the 1 in 100 year Probability event in King's Lynn LFRZ 1.

Table 3-1 Summary of local flood risk within the LFRZ 1 - Green Lane

Flood Classification/ Type	Source	Pathway	Receptor
Overland flow	In extreme rainfall events surface water runoff from both greenfield and urban areas generate an overland flow path into the LFRZ.	Due to the topography of the area a natural overland flow path is conveyed into the LFRZ from higher ground	Predominantly garden.
Ponding of surface water (in topographic low spots)	Natural valleys, depressions and topographic low spots.	There are two areas of ponding; one north of Green Lane and one north of Stody Drive. This is as a result of the A148 being at a higher elevation and creating an obstruction to flow	Residential properties adjacent to ponding areas.
Hazard	Moderate and significant hazards are expected within the area of ponding, but not within the overland flow path.		
Sewer	Combination of combined and separated drainage infrastructure of varying size (150mm – 525mm)		
Validation	The hydraulic modelling undertaken as part of this study indicates a greater area of flooding than that identified within the EA Flood Map for Surface Water (FMfSW) flooding. This can be attributed to more accurate LiDAR being used within the SWMP model.		
Groundwater	The LFRZ is not identified on the EA Areas Susceptible to Ground Water Flooding (AStGWF) map.		

LFRZ 2 – Wootton Drift

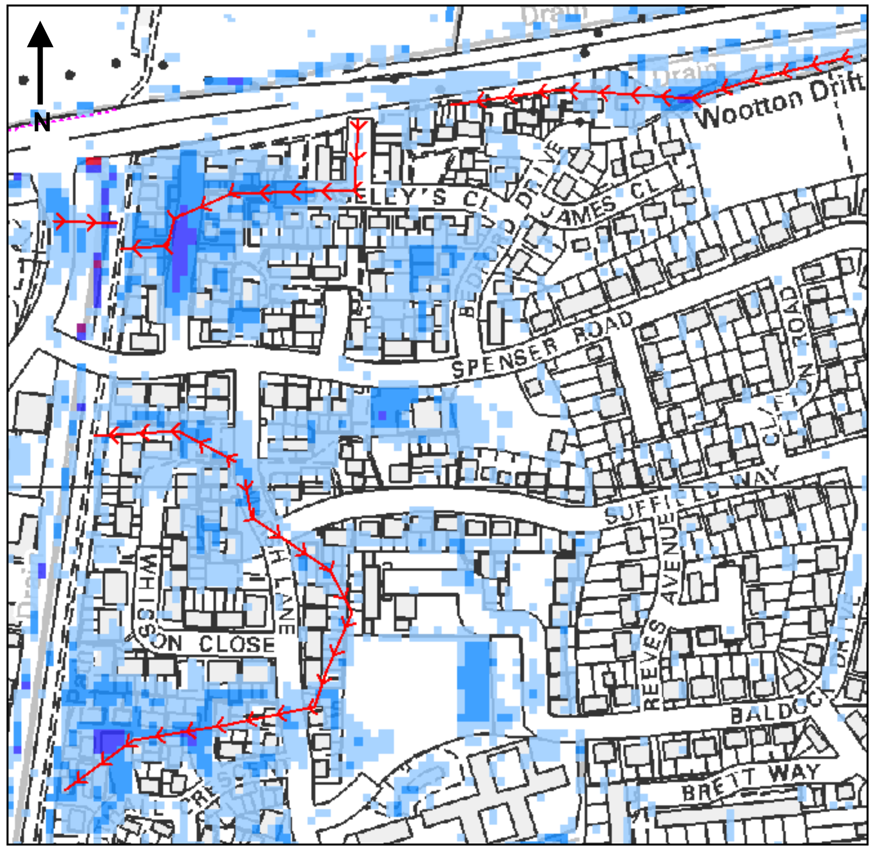


Figure 3-4 Flood Depth and Hazard for the 1 in 100 year Probability event in King's Lynn LFRZ 2

Table 3-2 Summary of local flood risk within the LFRZ 2 Wootton Drift

Flood Classification/ Type	Source	Pathway	Receptor
Overland flow	In extreme rainfall events, surface water runoff from the urban environment creates an overland flow path within the LFRZ. Excess runoff from the Wootton Drift may contribute runoff into the LFRZ	Due to the topography of the area, a natural overland flow path is conveyed into the LFRZ from higher ground	Predominantly residential areas (gardens)
Ponding of surface water (in topographic low spots)	Natural, depressions and topographic low areas.	There are two areas of ponding; one north of Nuthall Crescent and one within Clifford Burman Close.	Residential properties adjacent to ponding areas.
Validation	A historic incident was recorded near the LFRZ. The site inspection indicated a topographic low point in this location which adds confidence to the results. A review for the FMfSW indicate a good correlation with extent but a variance in depth as a result of the different ground modelling information used within the new model		
Hazard	Predominantly low flood risk within the LFRZ. Some areas of moderate and significant hazards are predicted within the area of ponding but not within the overland flow path.		
Sewers	Separated drainage infrastructure of varying size (150mm – 525mm)		
Groundwater	The EA AStGWF maps indicate that the LFRZ is located within an area that is a less than 25% (< 25%) risk of flooding from groundwater sources.		

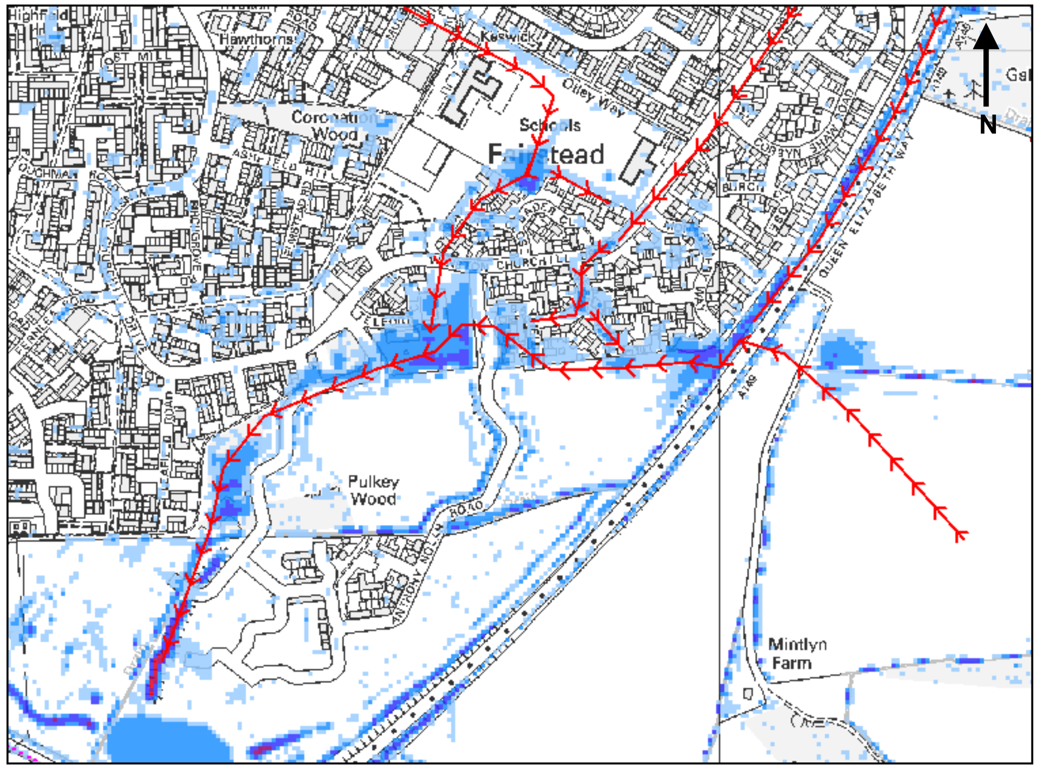
LFRZ 3 – Swan Lane, Gaywood

Figure 3-5 Flood Depth and Hazard for the 1 in 100 year Probability event in King's Lynn LFRZ 3

Table 3-3 Summary of local flood risk within the LFRZ 3 Swan Lane

Flood Classification/ Type	Source	Pathway	Receptor
Overland flow	In extreme rainfall events, surface water runoff from the urban environment will generate an overland flow paths within the LFRZ. Out of bank flooding may occur from the Gaywood River and contribute to flooding.	Due to the topography of the area a natural overland flow path is conveyed into the LFRZ from higher ground	Predominantly residential areas (gardens) with some residential flooding
Ponding of surface water (in topographic low spots)	Natural, depressions and topographic low spots.	There is one area of ponding; between Swan Lane and Eastfields Close constrained by an area of higher ground to the west.	Residential properties adjacent to ponding areas.
Validation	A review of the topography indicates that this overland flowpath could exist if the Gaywood River was at capacity and overland flow from areas south of the site could flow into the area. The flood extents are greater within the SWMP model – this could be attributed to the modelling of watercourses as 'bank full' and the more detailed DTM being used within the model.		
Hazard	Predominantly low flood risk with some areas of moderate flood risk.		
Sewers	Separated drainage infrastructure of varying size (predominantly 150mm and 300mm with some large pipes 450mm)		
Groundwater	The EA AStGWF maps indicate that the LFRZ is located within an area that is a less than 25% (< 25%) risk of flooding from groundwater sources.		

LFRZ 4 - Fairstead



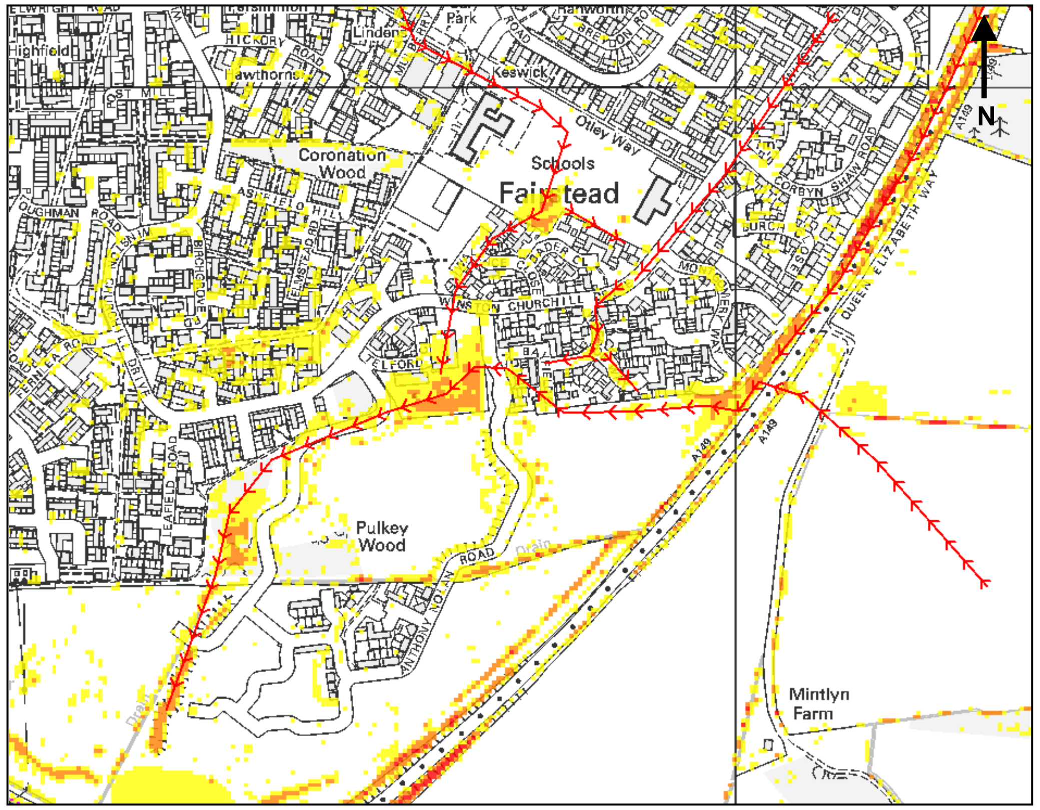


Figure 3-6 Flood Depth and Hazard for the 1 in 100 year Probability event in King's Lynn LFRZ 4

Table 3-4 Summary of local flood risk within the LFRZ 4 Fairstead

Flood Classification / Type	Source	Pathway	Receptor
Overland flow	In extreme rainfall events, surface water runoff from both Greenfield and urban environments will generate overland flow paths within the LFRZ.	Due to the topography of the area a natural overland flow path is conveyed into the LFRZ from higher ground	Predominantly open space flooding with residential areas and local streets impacted by flows
Ponding of surface water (in topographic low spots)	Natural, depressions and topographic low spots.	The area at greatest risk of flooding is located south of Winston Churchill Drive. The natural topography of this area directs flow paths into the local depression .	Residential properties adjacent to ponding areas and some streets.
Validation	There are three recorded incidents which support the modelling results. The site inspection also identified that topographic low points within the LFRZ would pond as predicted within the model. There is also generally a good correlation with the EA FMfSW with regards to flow regime; however the extents vary between the EA model and the SWMP model.		
Hazard	Predominantly low flood risk with some areas of moderate and significant flood risk, based on predicted flood depths.		
Sewers	Separated drainage infrastructure of varying size (between 150mm and 600mm).		
Groundwater	The LFRZ is not identified on the EA Areas Susceptible to Ground Water Flooding (AStGWF) map.		

LFRZ 5 – King's Lynn Centre

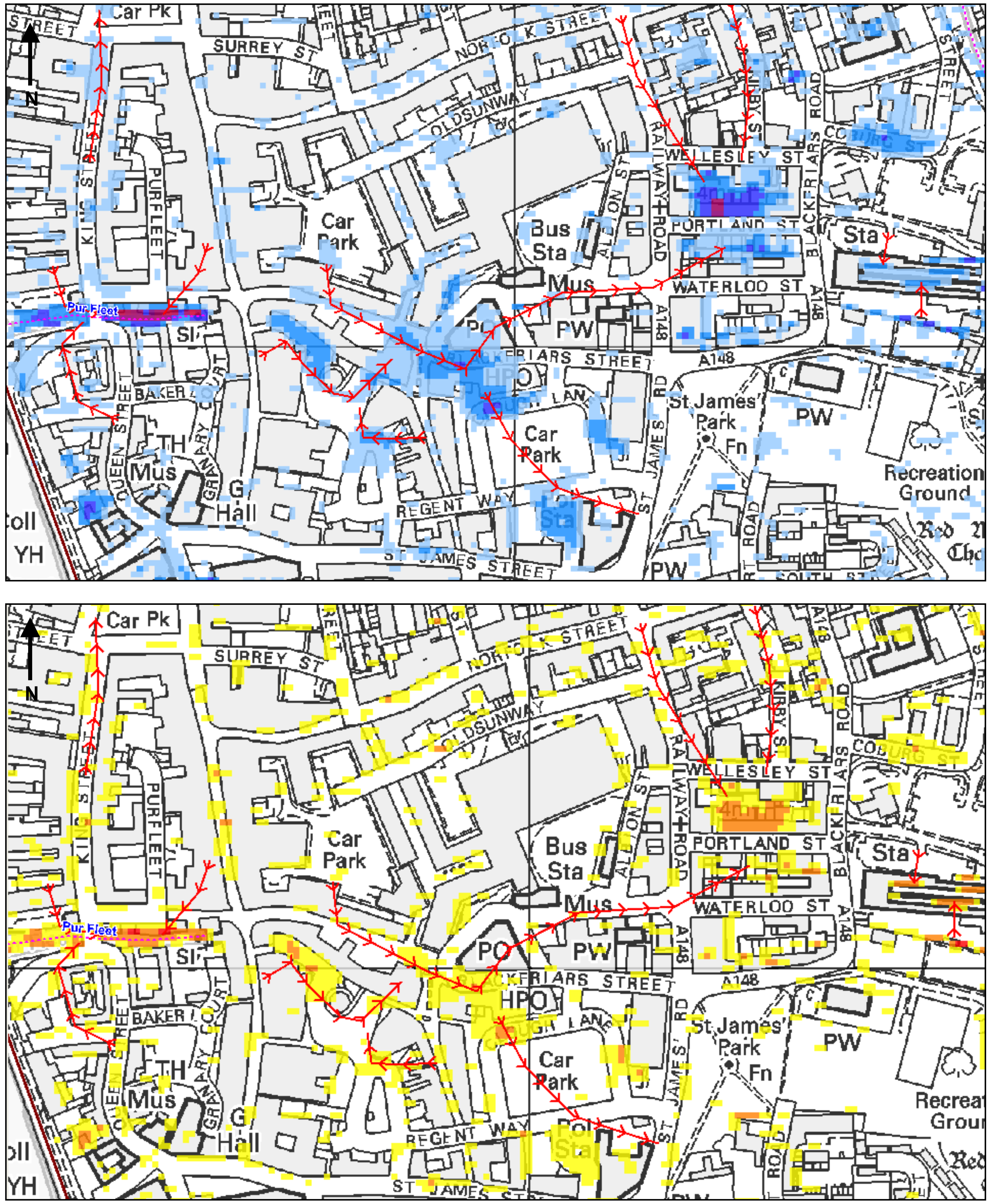


Figure 3-7 Flood Depth and Hazard for the 1 in 100 year Probability event in King's Lynn LFRZ 5

Table 3-5 Summary of local flood risk within the LFRZ 5 King's Lynn Centre

Flood Classification/ Type	Source	Pathway	Receptor
Overland flow	In extreme rainfall events, surface water runoff from the urban environments will generate overland flow paths within the LFRZ.	The area is relatively flat and natural overland flow paths are created which convey runoff into areas at lower elevations.	Predominantly commercial development, and minor roads.
Ponding of surface water (in topographic low spots)	Natural, depressions and topographic low spots.	The area at greatest risk of flooding is near Blackfriars Street and Clough Lane. The natural topography of this area directs flow paths into the local depression causing flooding. The area of flooding north of Portland Street appears to be a remnant of excessive LiDAR filtering and runoff from higher ground ponding in this location	Residential properties and commercial properties.
Validation	There are several recorded incidents which support the modelling results. The site inspection also identified that topographic low points within the LFRZ could pond as predicted within the model. Properties north of Portland Street may not pond as predicted – this is attributed to the process utilised to filter buildings and vegetation out of the LiDAR. There is also generally a good correlation with the EA FMfSW with regards to ponding locations; however the extents vary between the EA model and the King's Lynn model which could be attributed to model durations and the DTM used.		
Hazard	Predominantly low flood risk with some areas of moderate and significant flood risk, based on predicted flood depths.		
Sewers	Separated drainage infrastructure of varying size (between 150mm and 1,070mm)		
Groundwater	The EA AStGWF map indicates that the top left quadrant is within an area identified as having a high risk of groundwater emergence. The balance of the LFRZ is identified as having a moderate risk of groundwater emergence.		

LFRZ 6 – A47 Saddlebow Roundabout

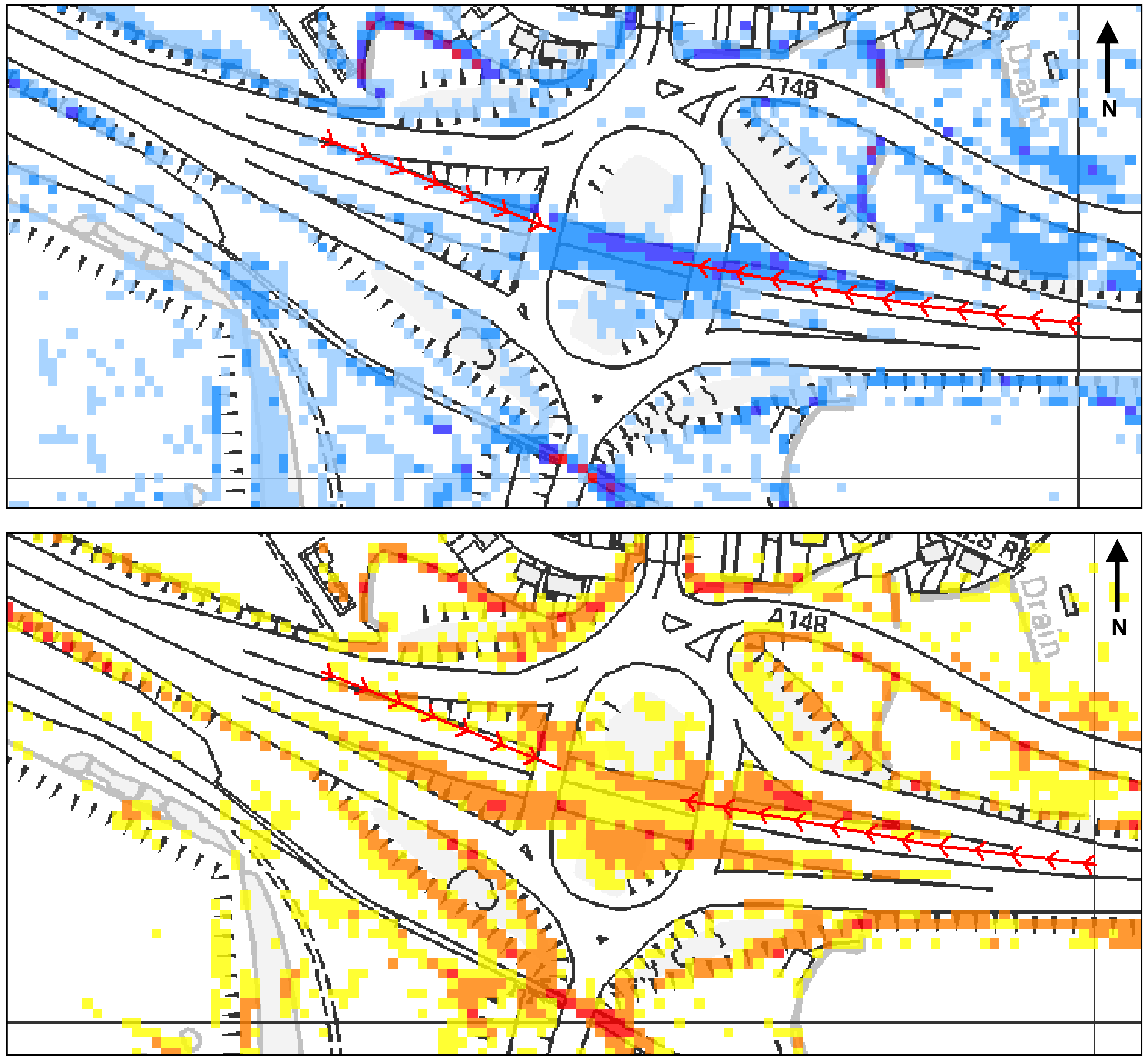


Figure 3-8 Flood Depth and Hazard for the 1 in 100 year Probability event in King's Lynn LFRZ 6

Table 3-6 Summary of local flood risk within the LFRZ 6 - A47

Flood Classification/ Type	Source	Pathway	Receptor
Ponding of surface water (in topographic low spots)	Natural, depressions and topographical low points.	Ponding within topographical low point within the A47.	Essential Infrastructure
Validation	There are no recorded flooding incidents within the LFRZ, but discussions with the Highways Agency confirm that they have had historic flooding at low points within the interchange area. This anecdotal information provides evidence that the model results are a fair representation of flooding in the LFRZ. A review of the EA FMfSW indicates a good correlation with area of ponding. However the depths and extents are greater in the revised modelling as a result of the improved DTM.		
Hazard	Predominantly low flood risk with large areas of moderate and significant flood risk, based on predicted flood depths.		
Sewers	Consultation with the Highways Agency indicates no pumping regime in place with drainage outlets discharging runoff into nearby drains.		
Groundwater	The EA AStGWF maps indicate that the LFRZ is located within an area that is at a low risk of groundwater emergence.		

3.3 Downham Market and Wimbotsham LFRZs

The town of Downham Market is the southernmost settlement modelled within the SWMP. The settlement is located east of the man made Relief Channel (which is classed as a Main River)

Nine historic flood events relating to water removal have been recorded in Downham Market – no additional details are provided in these records. These are predominantly located within the centre of the settlement.

The results of the intermediate level surface water modelling combined with site visits and a review of historical flood records, indicate that there is a moderate risk of surface water flooding within Downham Market. Figure 3-9 identifies the predicted flood extent during a 1 in 100 year probability event (1% AEP) along with the predicted overland flowpaths from the model.

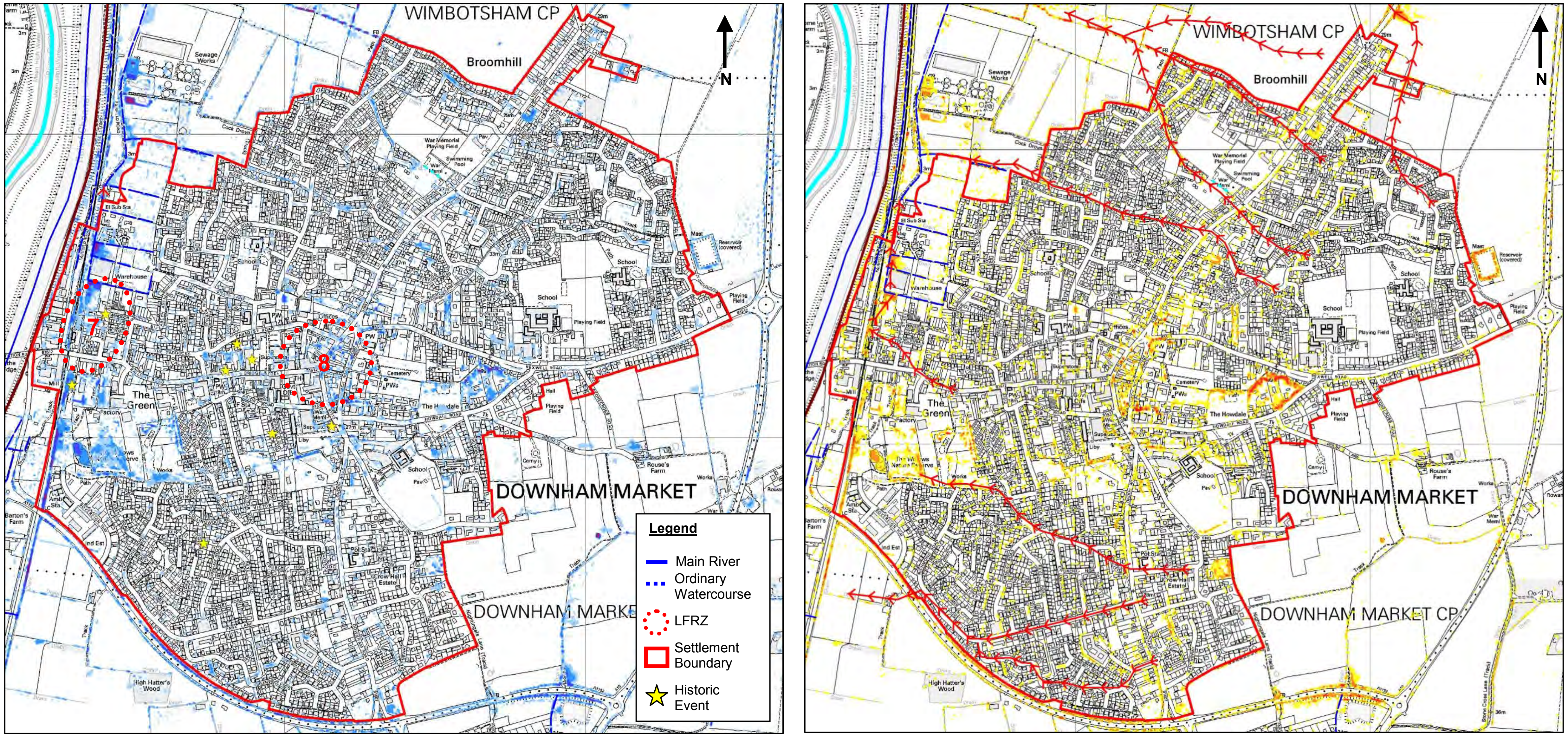


Figure 3-9 Local Flood Risk Zones within Downham Market (left) Primary Overland Flow Paths (right)

The EA AStGWF indicates Downham Market is outside of their analysis, but areas to the south and north are identified as being at a low risk of groundwater emergence.

LFRZ 7 – Railway Station and Electrical Sub-Station

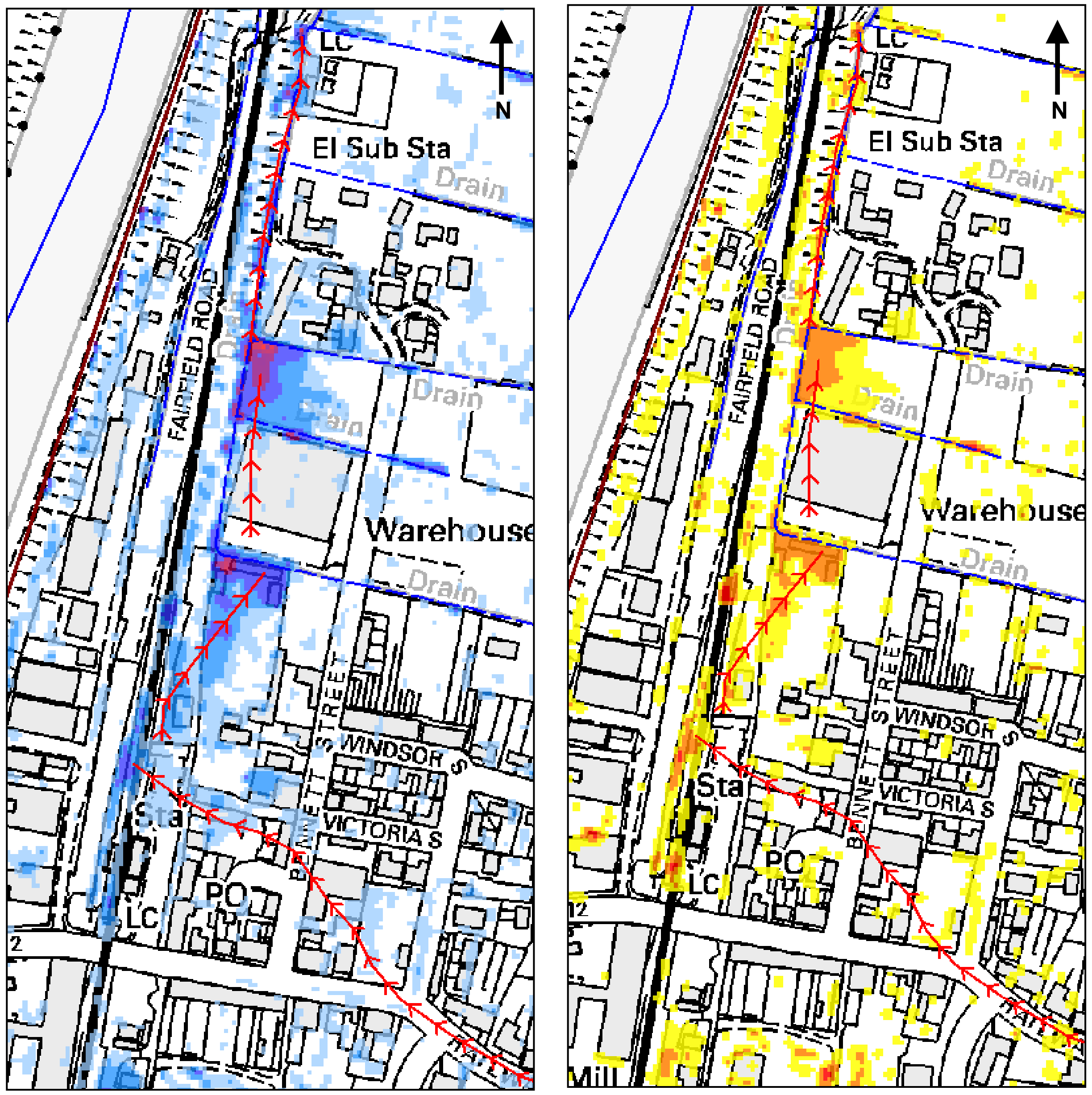


Figure 3-10 Flood Depth and Hazard for the 1 in 100 year Probability event Downham Market LFRZ 7.

Table 3-7 Summary of local flood risk within the LFRZ 7 - Railway Station and Electrical Sub-Station

Flood Classification/ Type	Source	Pathway	Receptor
Overland flow	In extreme rainfall events, surface water runoff from upstream areas creates minor flowpaths into low lying areas of the LFRZ.	Due to the topography of the area, a minor overland flow paths convey runoff from higher ground within the local catchment	Essential Infrastructure (rail and electricity).
Ponding of surface water (in topographic low spots)	Natural valleys, depressions and topographic low spots.	The two areas of concern are the Downham Market train station and electrical sub-station north of Otter Close	Essential Infrastructure (rail and electricity) and possible residential land uses
Hazard	Moderate and significant hazards are predicted within the areas of ponding. Overland flow paths are predicted to be of a low hazard		
Sewer	Site inspections of the rail line indicate that a drainage network is in use but its details were not provided for this study. Drainage information provided by Anglian Water indicates foul sewers running parallel to the rail line.		
Validation	There is one recorded flood incident on Bennett Street – however the cause of this flooding is not known. A site inspection of the rail line indicates that this flood extent maybe a result of the model DTM and grid size between tracks and platforms artificially 'ponding water. No site inspection of the substation was undertaken and no information on the site drainage was available at the time of writing. The hydraulic modelling undertaken as part of this study indicates a greater area of flooding than that identified within the EA Flood Map for Surface Water (FMfSW) flooding, however the locations of flooding appear to be consistent. This can be attributed to more accurate LiDAR being used within the new model and a difference in model durations.		
Groundwater	The LFRZ is not identified on the EA Areas Susceptible to Ground Water Flooding (AStGWF) map.		

LFRZ 8 – High Street

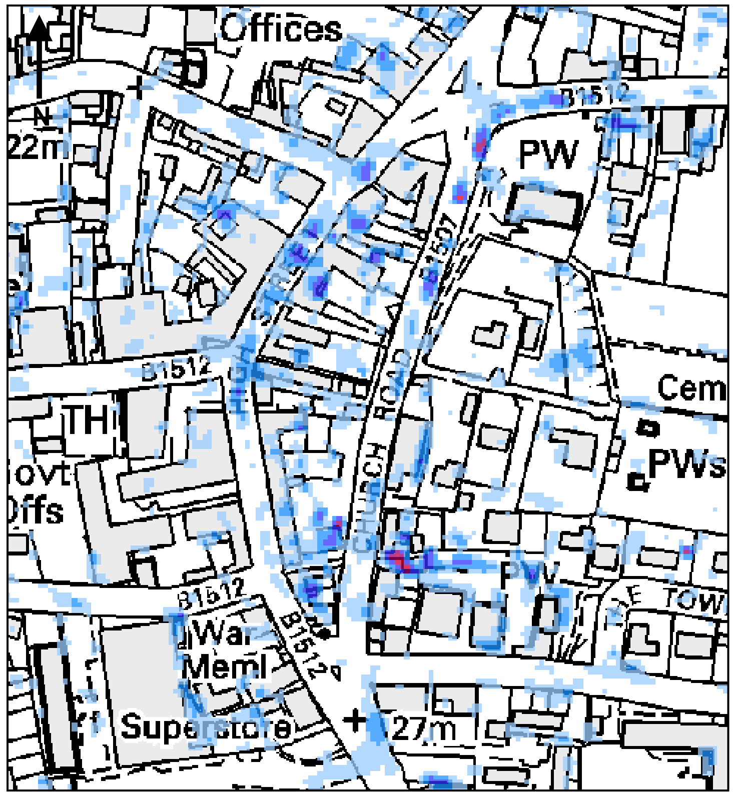


Figure 3-11 Flood Depth and Hazard for the 1 in 100 year Probability event Downham Market LFRZ 8

Table 3-8 Summary of local flood risk within the LFRZ 8 - High Street

Flood Classification/ Type	Source	Pathway	Receptor
Overland flow	In extreme rainfall events, surface water runoff from upstream areas creates minor flowpaths into low lying areas of the LFRZ.	The area is relatively flat and natural overland flow paths are created which convey runoff into areas at lower elevations.	Residential and commercial
Ponding of surface water (in topographic low spots)	Natural valleys, depressions and topographic low points.	Ponding is dispersed throughout the area of local topographical low points	Residential properties adjacent to ponding areas.
Hazard	Moderate and significant hazards are expected within the area of ponding.		
Sewer	Predominantly combined with some separated drainage infrastructure within the LFRZ. Size of pipes vary between 150mm – 300mm		
Validation	The dispersed nature of the flooding may be an artificat of the LiDAR filtering process or the ponding of water behind property thresholds. The hydraulic modelling undertaken as part of this study indicates a greater area of flooding than that identified within the EA Flood Map for Surface Water (FMfSW) flooding. This can be attributed to the DTM used within the new model.		
Groundwater	The LFRZ is not identified on the EA Areas Susceptible to Ground Water Flooding (AStGWF) map.		

Wimbotsham

Wimbotham is located north of Downham Market. The hydraulic model for Downham Market also included the settlement of Wimbotsham, as it was identified as being within the contributing catchment. The results from the hydraulic model can be found within Figure 3-12 below. The flood risk from surface water within Wimbotsham is concluded as being low and no LFRZs being identified within the settlement.

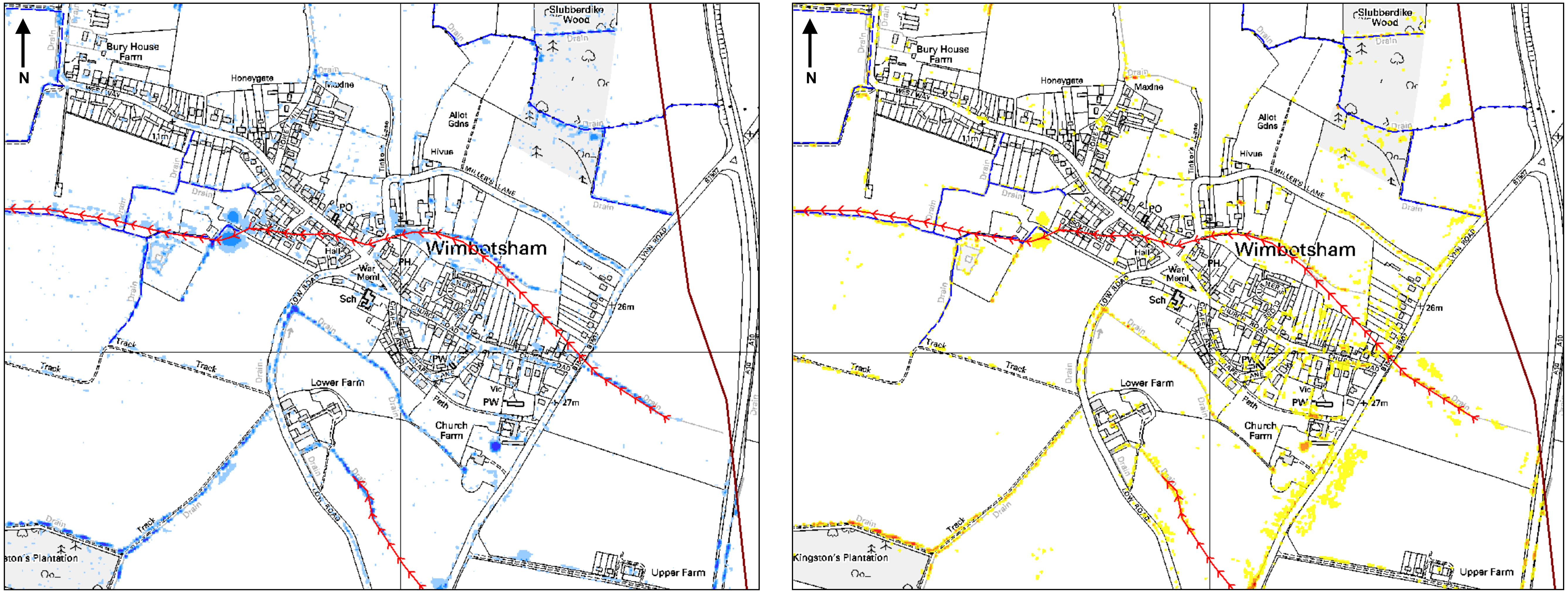


Figure 3-12 1 in 100 year probability event rainfall depths (left) and hazard (right) within Wimbotsham

The site inspection concluded that drainage within the centre of settlement is generally in poor condition. It is not thought that sewer surcharging would lead to SW flooding within the settlement, however poor drainage would be overwhelmed during an extreme event and runoff could flow overland towards the centre of the settlement to the west of the playing field (near the village hall).

Anglian Water records indicate that the majority of Wimbotsham utilises a combined foul drainage network to manage runoff within the settlement – there is one portion in the north east of the settlement which has a seperate network. There is limited information relating to the size of this network, with the exception of the northeast of the settlement where pipe sizes are predominantly 150mm diameter and the surface water network includes pipes of up to 1200mm which indicates is possibly an attenuation feature of the recent development near Napthans Lane.

The EA AStGWF indicates Wimbotsham is considered as having a low chance of groundwater emergence, with the risk to moderate directly east of the settlement.

3.4 Snettisham LFRZs

Snettisham is located within the north east of the Borough. The results of intermediate level surface water modelling combined with site visits, and a review of historical flood records, indicate that there is a low risk of significant surface water flooding within the settlement. No historic flooding events have been recorded within the settlement and the direct rainfall modelling indicates minor areas of ponding within topographic low points ('sags' in roads, gardens etc) within the settlement. Flooding within the Anchor Park site is identified to occur from the ordinary watercourse. Flow from the River Ingol (contributing watercourse) is obstructed by the Lynn Road. Runoff will pond behind Lynn Road until it reaches a level in which flows overtop the embankment and creates an overland flow path which flows through the site before re-entering the unnamed drain along the properties' southern boundary. Figure 3-13 illustrates the predicted flood extent (and hazard) during a 1 in 100 year probability rainfall event (1% AEP).

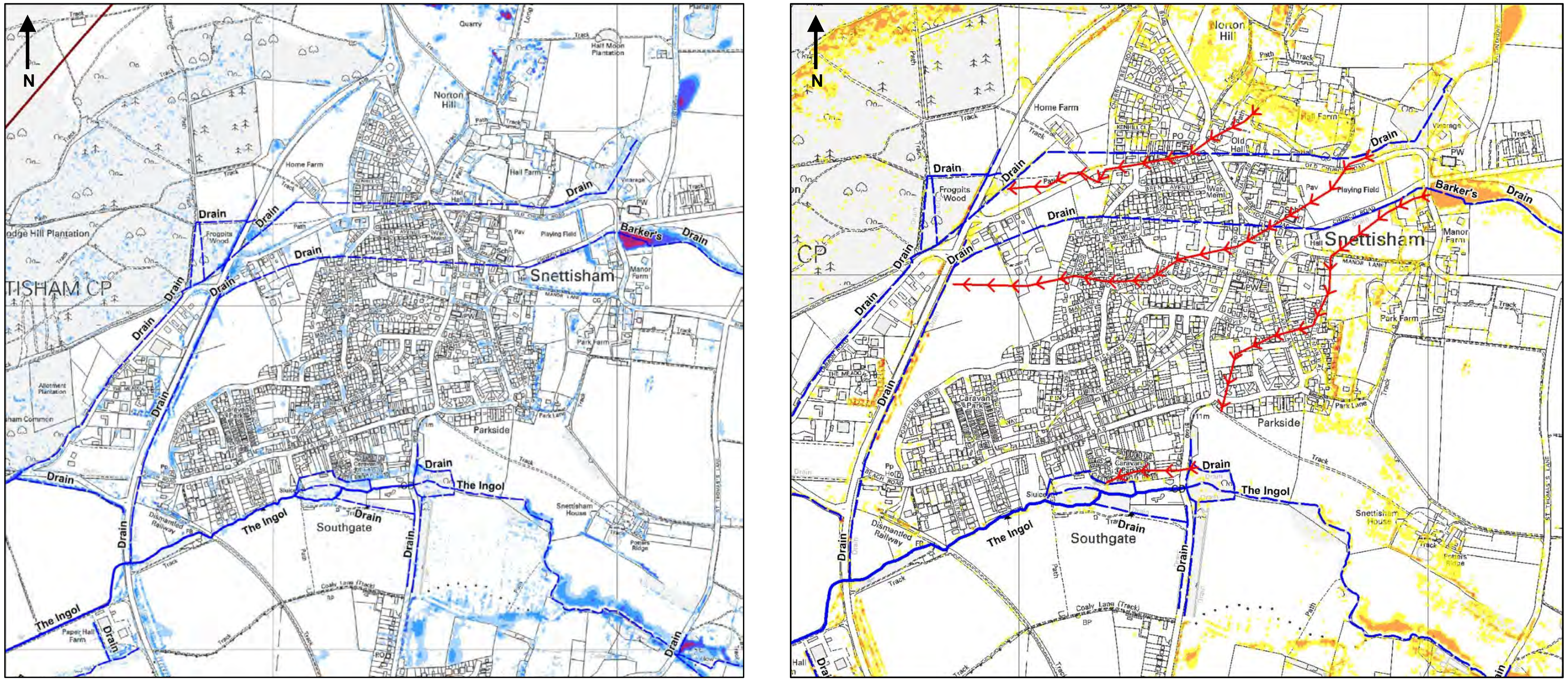


Figure 3-13 1 in 100 year probability event rainfall depths (left) and hazard (right) within Snettisham

Anglian Water records indicate that the majority of Snettisham utilises a separated drainage network to manage runoff within the settlement. There is limited information relating to the size of this network, with only some segments of the network sizes being identified near the Meadow Sweet Close area. These pipes are identified as being between 150mm – 750mm.

The EA AStGWF indicates that the western portion of the Snettisham is considered to have a low risk groundwater emergence. However, this risk of emergence increases to moderate in the northeast and high in the southeast of the settlement (refer to Figure 3-14).

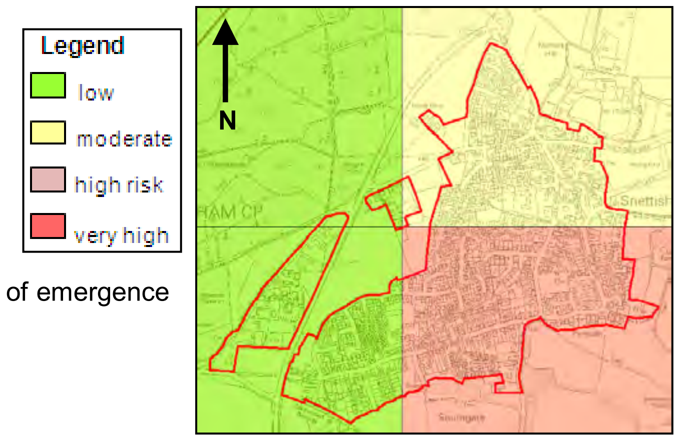
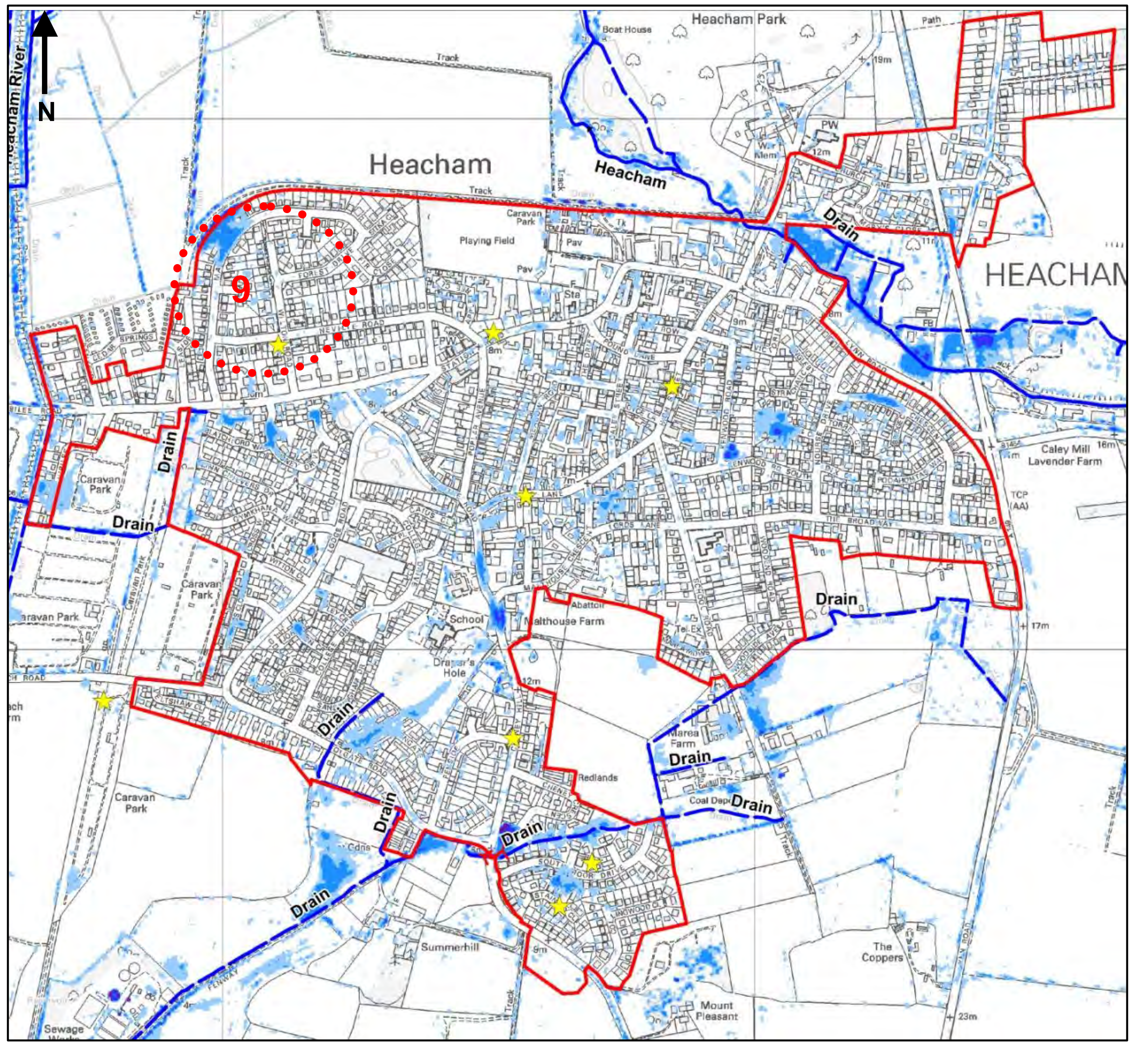
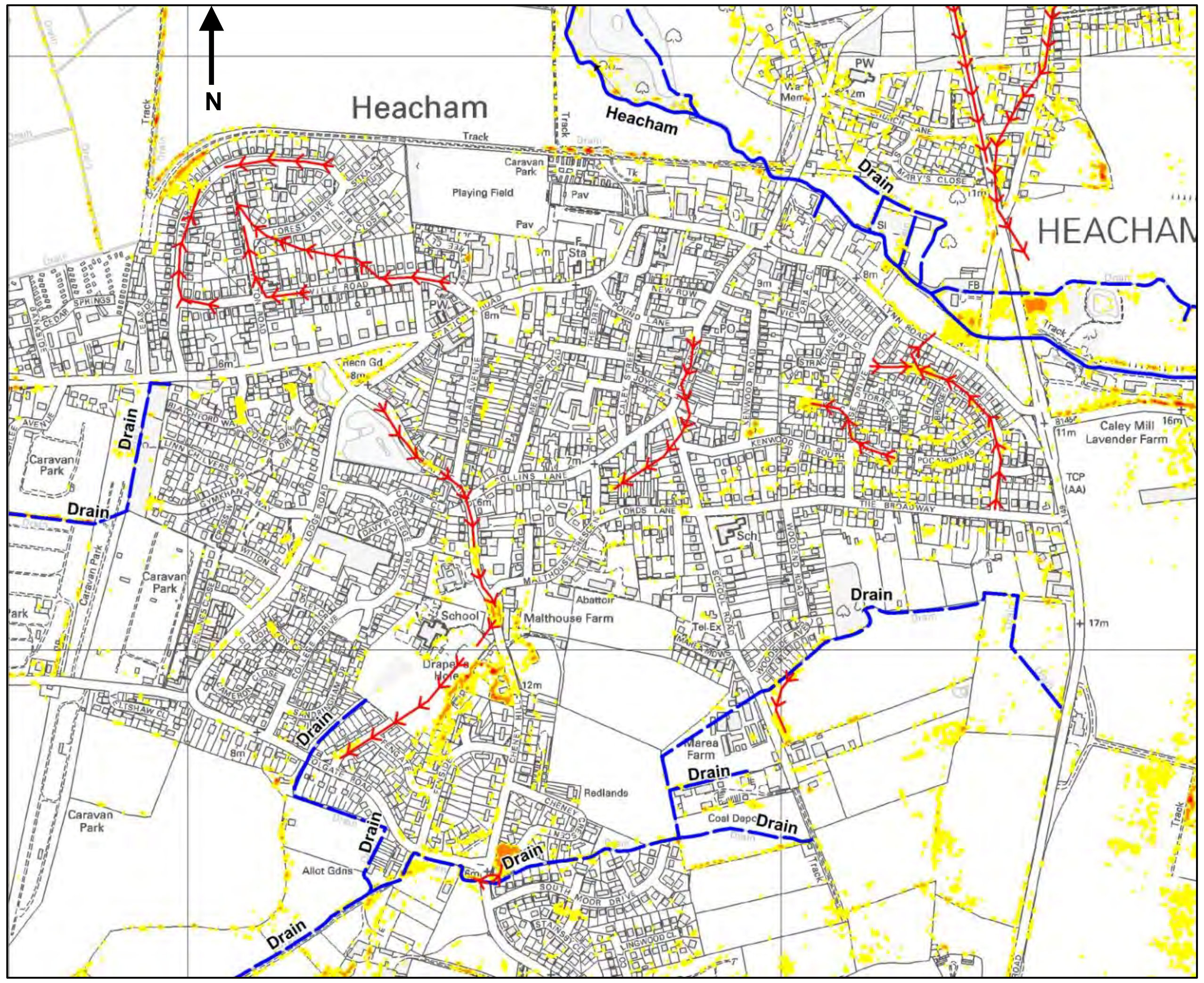


Figure 3-14 AStGWF Map for Snettisham

3.5 Heacham LFRZs

The parish of Heacham is located in the north east of the Borough, directly north of Snettisham. The results of intermediate level surface water modelling combined with site visits and a review of historical flood records indicate that there is a moderate risk of surface water flooding within the settlement – typically associated with topographic low points.





Anglian Water records indicate that the centre of Heacham uses a combined drainage network. Areas in the northeast and northwest utilise a separated drainage network to manage runoff into either the River Heacham or the nearby watercourses. There is limited information relating to the size of these networks and should be investigated as part of the Action Plan.

The EA AStGWF indicates Heacham is considered to have (refer to Figure 3-15):

- A low risk of emergence in a small western and north eastern portion of the settlement.
- A moderate risk of emergence in the southern and eastern areas; and
- A high risk of emergence in the centre of the settlement.

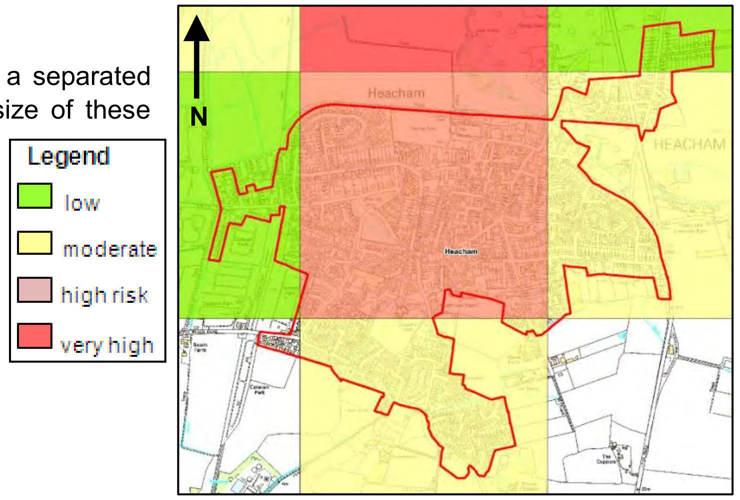
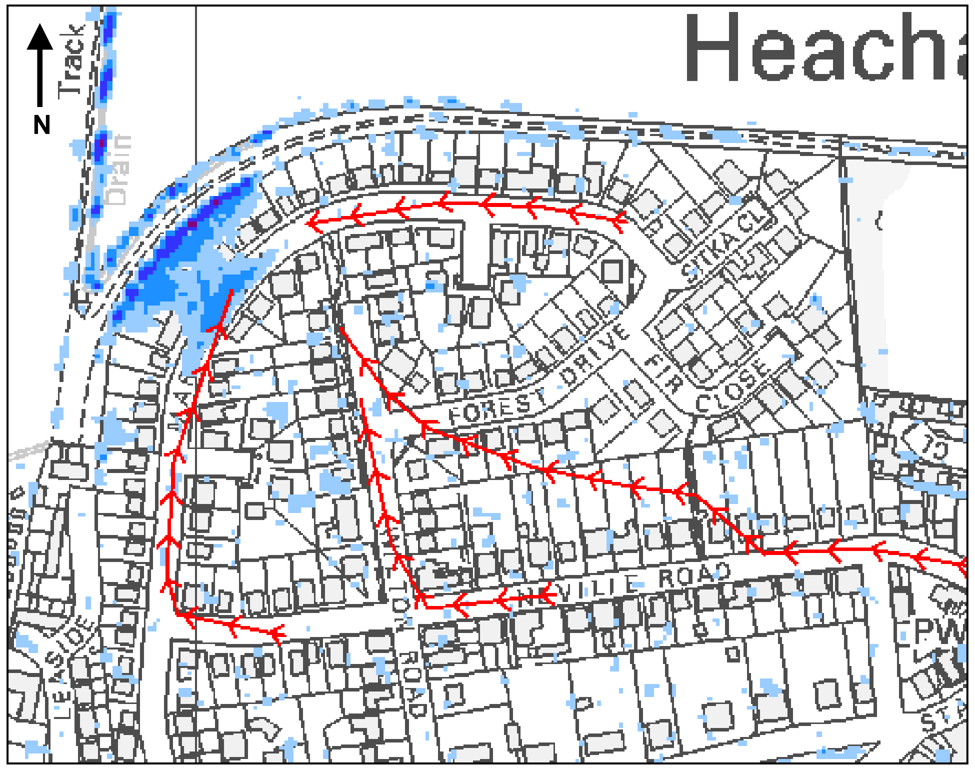


Figure 3-15 AStGWF Map for Heacham

LFRZ 9 – Marram Way



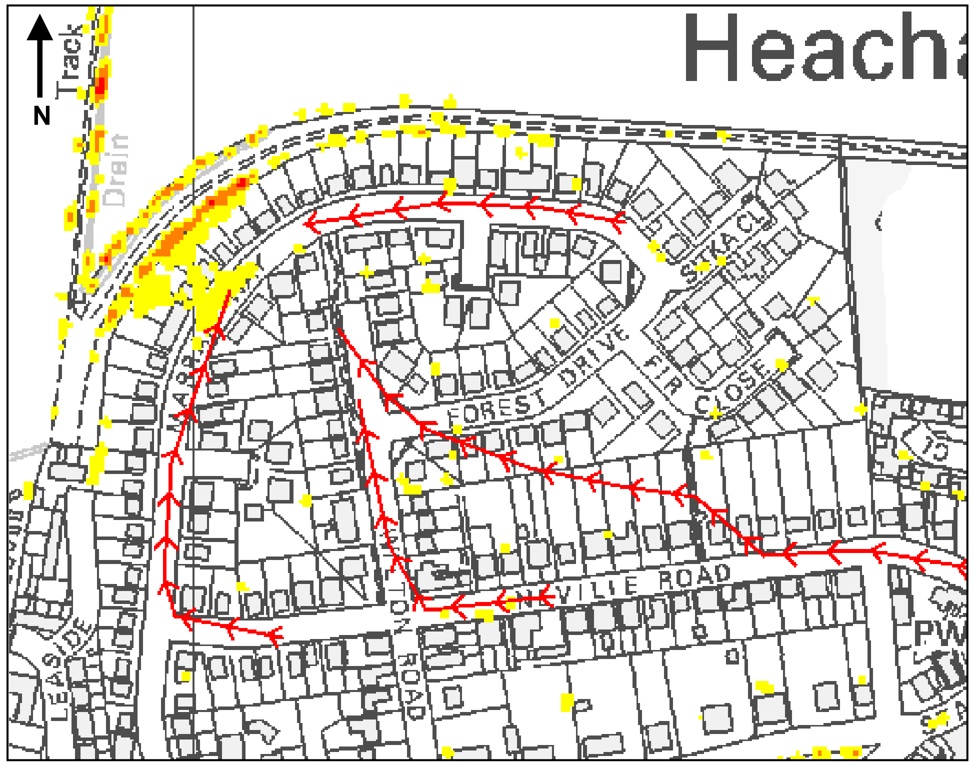


Figure 3-17 Flood Depth and Hazard for the 1 in 100 year Probability event LFRZ 9.

Figure 3-16 Flood Depth and Hazard for the 1 in 100 year Probability event LFRZ 9.

Flood Classification/ Type	Source	Pathway	Receptor
Overland flow	In extreme rainfall events, surface water runoff from upstream areas creates minor flowpaths into the LFRZ.	Due to the topography of the area, minor overland flow paths convey runoff from higher ground within the local catchment	Minor roads and gardens
Ponding of surface water (in topographic low spots)	Topographic low with a raised ground (in the NW) which obstructs flows and promoted ponding.	Flooding within Marram Way is generated by overland flow being trapped behind the raised track (former Burnham Market Railway Line) along the LFRZ north western boundary	Minor road and properties
Hazard	The majority of the LFRZ is at a low risk. However, both moderate and significant hazards are predicted within the area of ponding. Overland flow paths are predicted to be of a low hazard.		
Sewer	Drainage information provided by Anglian Water indicates that foul sewers (combined network) contained within the area. A pumping station is located within the centre of the LFRZ but not near the area of ponding.		
Validation	Site inspection (and discussions with locals) indicates that this is an area that has previously flooded and the Anglian Water Pump station is often overwhelmed during large storm events. The hydraulic modelling undertaken as part of this study indicates a greater area of flooding in the EA FMfS) flooding, however the locations of flooding appear to be consistent. This can be attributed to more accurate LiDAR being used within the new model which may have created alternative flowpaths within the settlement, thus reducing the volume of runoff flowing into the low point.		
Groundwater	The EA AStGWF map indicates that the majority of the LFRZ is within an area identified as having a high risk of groundwater emergence.		

3.6 Flood Risk Summary – Modelled Settlements

3.6.1 Overview of Flood Risk in King's Lynn and West Norfolk

The results of the intermediate level risk assessment, combined with site visits and a detailed review of existing data and historical flood records, indicate that there is moderate risk of flooding in King's Lynn and West Norfolk from surface water, groundwater, ordinary watercourses and sewer flooding.[4] Although flood risk is very widely dispersed across the study area, the highest level of risk is concentrated in the centres of King's Lynn and Downham Market.

It is acknowledged that flooding within the Borough is not limited to the identified LFRZs; in fact there are several localised areas at risk of surface water flooding. These should be assessed and analysed in the future.

In general, flooding across the Borough is relatively minor during lower order rainfall events (such as a 1 in 30 year event) but is predicted to experience more severe flooding across the study area during higher order events (such as a 1 in 100 year event). This is reflected in the analysis of risk to properties, businesses and infrastructure that is discussed below.

3.6.2 Risk to Existing Properties & Infrastructure

Maps of predicted flood depths and extents which have been generated from the surface water modelling results are included in Appendix C. In order to provide a quantitative indication of potential risks, building footprints (taken from the OS MasterMap dataset) and the National Receptor Dataset have been overlaid onto the modelling outputs in order to estimate the number of properties at risk within the study area. The National Receptor Dataset is not entirely comprehensive and may not include all known or recent properties. Table 3-9 and Table 3-10 identify the categories used in the assessment of flooded properties.

Table 3-9 Infrastructure Sub-Categories

Category	Description
Essential Infrastructure	• Essential transport infrastructure which has to cross the area at risk • Mass evacuation routes • Essential utility infrastructure which has to be located in a flood risk area for operation reasons • Electricity generating power stations and grid and primary substations • Water treatment works
Highly Vulnerable	• Police stations, Ambulance stations, Fire stations, Command Centres and telecommunications installations • Installations requiring hazardous substances consent
More Vulnerable	• Hospitals • Health Services • Education establishments, nurseries • Landfill, waste treatment and waste management facilities for hazardous waste • Sewage treatment works • Prisons

[4] Methodology and limitations relating to each source of flooding can be located within Section 2.

Table 3-10 Household and Basement Sub-Categories

Category	Description
Households	• All residential dwellings • Caravans, mobile homes and park homes intended for permanent residential use • Student halls of residence, residential care homes, children's homes, social services homes and hostels
Deprived Households	• Those households falling into the lowest 20% of ranks by the Office of National Statistics' Indices of Multiple Deprivation.
Non-Deprived Households	• Those households not falling into the lowest 20% of ranks by the Office of National Statistics' Indices of Multiple Deprivation
Basements	• All basement properties, dwellings and vulnerable below ground structures (where identified in existing dataset including those provided by Thames Water and Environment Agency's National Receptor Database).

Table 3-11 below, indicates the approximate number of properties and critical infrastructure which may be affected in each of the modelled settlements during a 1 in 100 year probability rainfall event (1% AEP).

Table 3-11 Flooded Properties Summary 1 in 100 year probability event – Depths > 10cm

Property Type	Flood Risk Vulnerability Classification	Model			
		Downham Market	Heacham	Kings Lynn	Snettisham
Infrastructure	Essential Infrastructure	2	0	1	0
	Highly Vulnerable	0	0	1	0
	More Vulnerable	2	0	2	1
	Sub-total	**2**	**0**	**3**	**1**
Households	Non-Deprived (All)	71	30	324	21
	Non-Deprived (Basements Only)	0	0	0	0
	Deprived (All)	0	0	148	0
	Deprived (Basements Only)	0	0	0	0
	Sub-total	**71**	**30**	**472**	**21**
Commercial / Industrial	Units (All)	12	0	45	1
	Units (Basements Only)	0	0	0	0
Others	Other Flooded Properties	0	0	1	0
	Unclassified Flooded Properties	63	22	125	25
	Infrastructure Other	0	0	3	0

An analysis was also carried out to determine the risk to properties and infrastructure from a lower order rainfall event, which would have a higher probability of occurring. The 1 in 30 year probability event (3.3% AEP) was used for this assessment and the results are summarised in Table 3-12 below.

Figure 3-18, below, identifies the difference in flooded properties between the two events.

Table 3-12: Flooded Properties Summary 1 in 30 year probability event – Depths > 10cm

Property Type	Flood Risk Vulnerability Classification	Model			
		Downham Market	Heacham	Kings Lynn	Snettisham
Infrastructure	Essential Infrastructure	1	0	1	0
	Highly Vulnerable	0	0	0	0
	More Vulnerable	2	0	1	0
	Sub-total	**3**	**0**	**2**	**0**
Households	Non-Deprived (All)	52	11	183	14
	Non-Deprived (Basements Only)	0	0	0	0
	Deprived (All)	0	0	114	0
	Deprived (Basements Only)	0	0	0	0
	Sub-total	**52**	**11**	**297**	**14**
Commercial / Industrial	Units (All)	14	0	39	1
	Units (Basements Only)	0	0	0	0

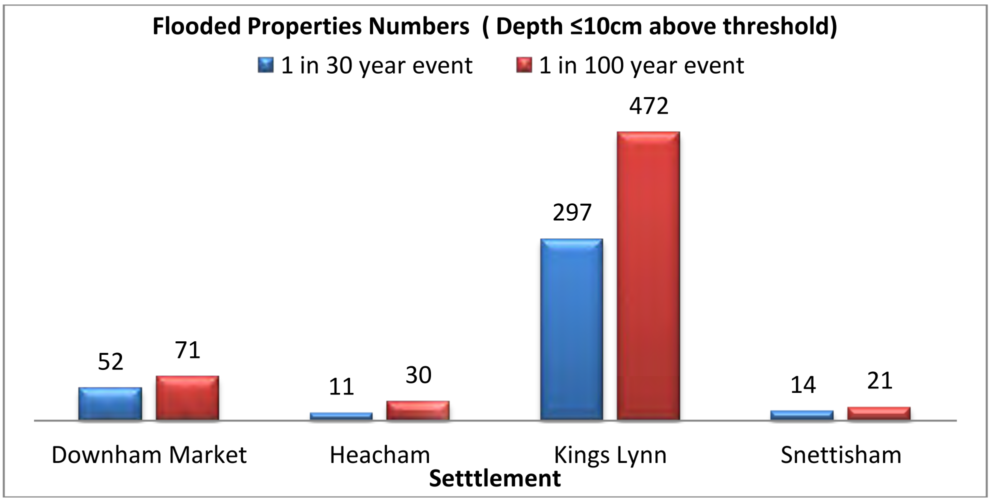


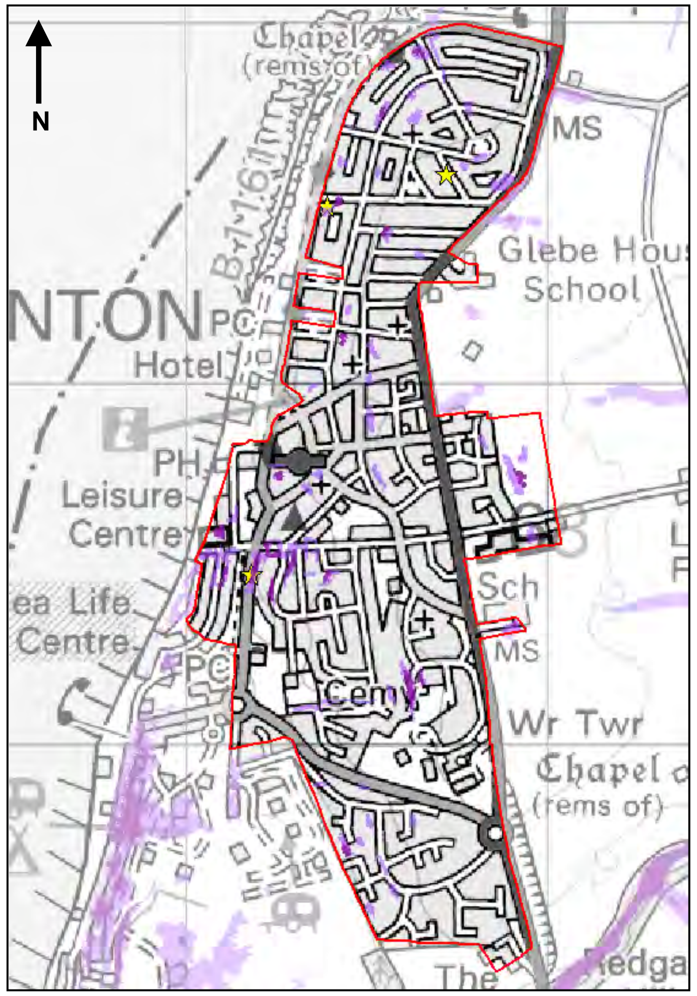
Figure 3-18 Graph Comparing the Number of Properties at Risk from Surface Water Flooding

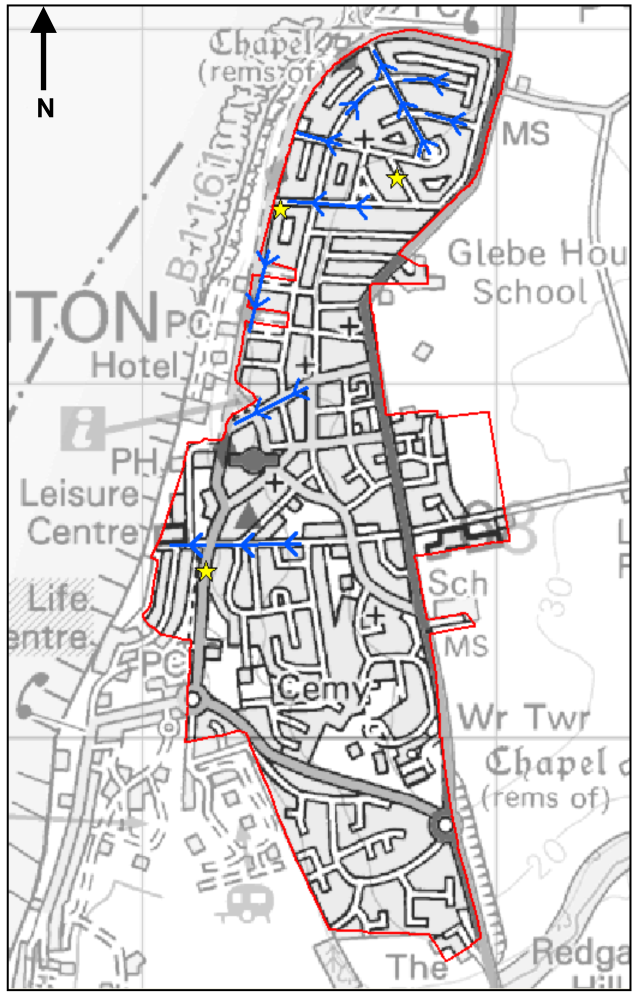
As shown, King's Lynn has the greatest amount of properties at risk from the 1 in 30 year probability event (3.3% AEP) and the 1 in 100 year probability event (1% AEP) – this is expected as it is the most densely populated settlement.

3.7 Flood Risk – Non Modelled Settlements

The following section provides an interpretation of the risk of surface water flooding to the non-modelled settlements based on the Environment Agency Flood Maps for Surface Water and the site inspections undertaken as part of this study. It also provides a summary of the current drainage infrastructure utilised within the town and assesses the risk of groundwater flooding from the EA AStGWF dataset.

3.7.1 Hunstanton





Legend:

- Settlement Boundary
- Historic Event
- Overland flowpath
- FMfSW 1 in 200 year >10cm depth
- FMfSW 1 in 200 year >30cm depth

Sewers – The settlement predominantly uses a separated drainage network with the majority of pipe sizes being between 150mm and 225mm.

Pumping Stations - There are pumping stations in the north of the settlement, near Lighthouse Close (for foul purposes), three near the South Beach Road roundabout, and one near Annes Drive in the south of the settlement. Drainage typically discharges directly into The Wash.

Groundwater – the risk within the settlement varies from low in the north, moderate in the centre and high in the south.

General Comments:

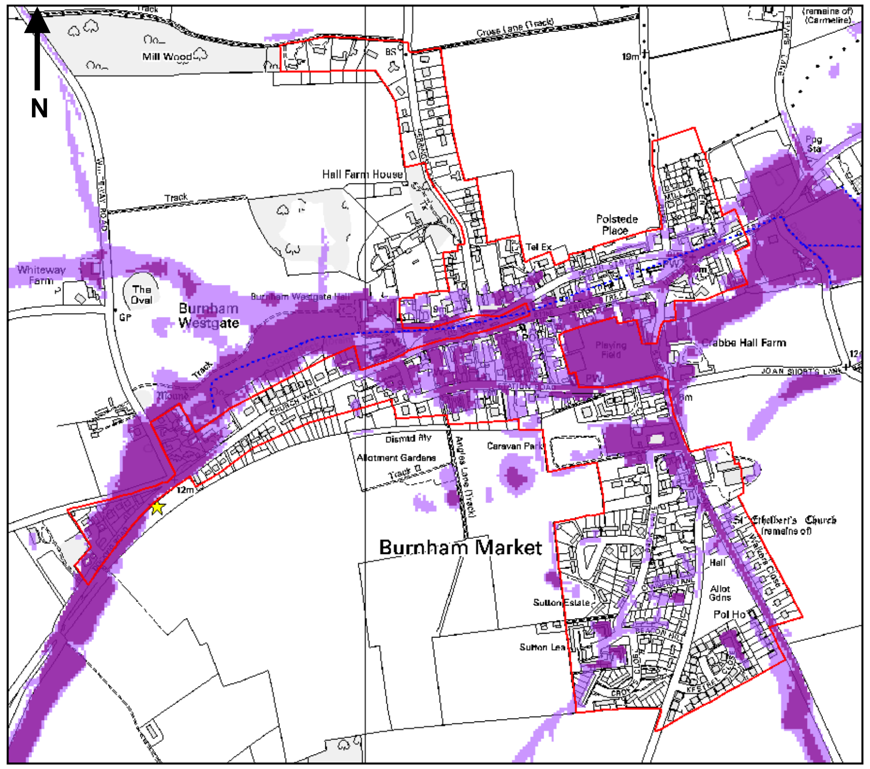
North/Central Hunstanton

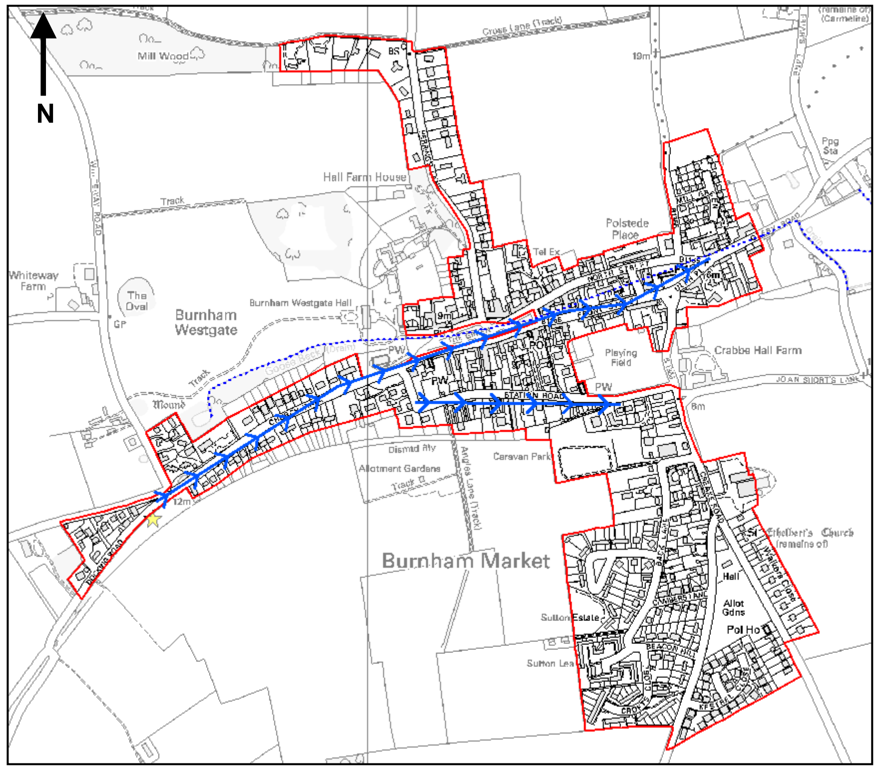
Flooding shown in the area of Old Town Quay, Queens Drive/Gardens and Clarence Road is likely to be caused by relatively small pipe diameters and a generally flat topography. A plateau is located to the east of the cul-de-sac (Queens Gardens) and it is likely that the drainage system has a limited capacity as a result. It is likely that standing water which cannot enter the drainage system, will accumulate and flow along local roads and possibly into gardens. The critical surface water flow route in the area is considered to be down Queens Drive and Kings Road – two historic flood events have been recorded near these areas. The site inspection confirms that water could pond at the Queens Drive/Cliff Parade junction to a possible depth of 0.3m. At the low areas on Cliff Parade, the topography is generally flat and the drainage system may experience difficulties draining. This could be exacerbated by the steep contributing catchment, creating a rapid flashy surface water event which exceeds the capacity of the network. It is therefore likely that surface water, and even foul water, may surcharge at the low points and may affect gardens and local properties.

South Hunstanton

There is a record of surface water flooding in the area on Southend Road, near to the junction of Park Road. The site inspection indicates that there is evidence to suggest that surface water flooding may occurs frequently and attempts have been made to manage the flood risk (increased gulley inlet numbers/ local increase in pipe size). Although the road is low-lying, the volume of overland flow draining to this point is not considered significant, as runoff along Park Road (to the north) would continue to flow west and bypass this area. This observation suggests that surface water flooding may have resulted from sewer flooding. Similar to the problem occurring on Queens Gardens (in the north of the settlement), it appears that the drainage system, and overland flow path, is steep to the east and as flows and runoff 'hit' the flat section of the system, there is sufficient pressure to surcharge the manholes in front of the existing Suzuki garage. An overland flooding regime could be created, resulting from surface water on the road being unable to re-enter the drainage system and therefore contributing to flooding elsewhere within the local catchment. Once the water depth reaches a approximately 0.2m, it could then combine with local flooding regime to the north and contribute towards ponding. Existing housing and a raised embankment form a man-made barrier which prevents overland flow from discharging flows into The Wash. Other roads within the centre appear to not include these obstructions and allow runoff to discharge unimpeded.

3.7.2 Burnham Market





Legend:

- Settlement Boundary
- Historic Event
- Overland flowpath
- FMfSW 1 in 200 year >10cm depth
- FMfSW 1 in 200 year >30cm depth

Sewers – a review of the Anglian Water data set indicates that the settlement utilises a combined drainage network. No sewer size information is available for the settlement with the exception of one link showing a 150mm pipe.

Pumping Station – foul drainage pumping station located near the junction of Friars Lane and Overy Road which pumps flows to the nearby Sewage Works.

Groundwater – the EA AStGWF indicates that the risk within the settlement varies from low in the west to moderate and high in the south east and north east respectively.

General Comments:

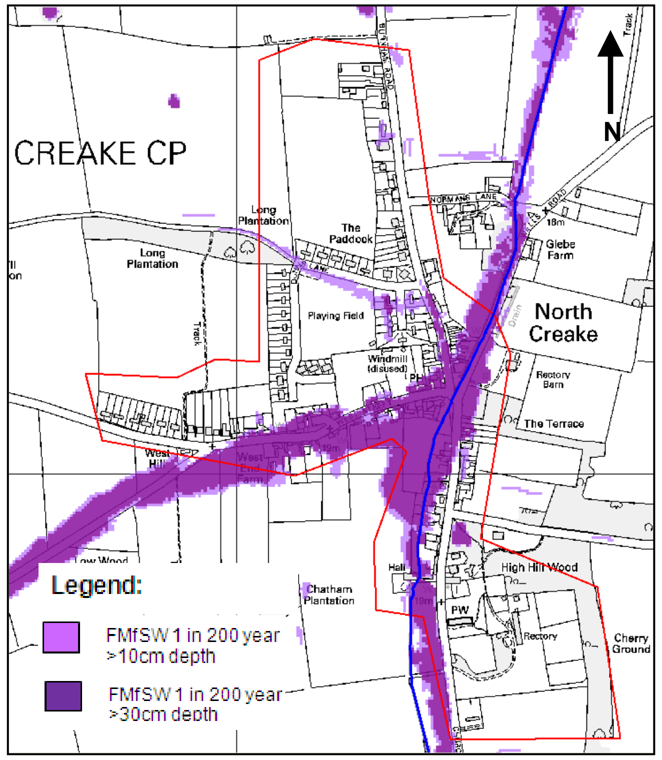
The Goose Beck, is a natural (ordinary) watercourse that drains the Goose Beck catchment and discharges flows into the River Burn. Since Burnham Market has been established, the settlement intercepts a majority of the overland flow from Goose Beck's catchment, and as a result the Beck has become a grass swale through an area referred to as 'The Green'. This 'swale' has been adopted as a storm water drain for excess road runoff, collecting stormwater that cannot be conveyed by the drainage system, with flow pathways and pipes connecting into the channel from the adjacent roads. Anecdotal information states that the swale is often full at the downstream end (eastern end), due to a high water table in the area, with groundwater flooding known to occur in cellars (discussions with local residents). Site inspections confirmed that the water table was generally high in the area as a result of its proximity to the River Burn and the local geology. There is the potential for some properties to be affected by groundwater flooding following rainfall events.

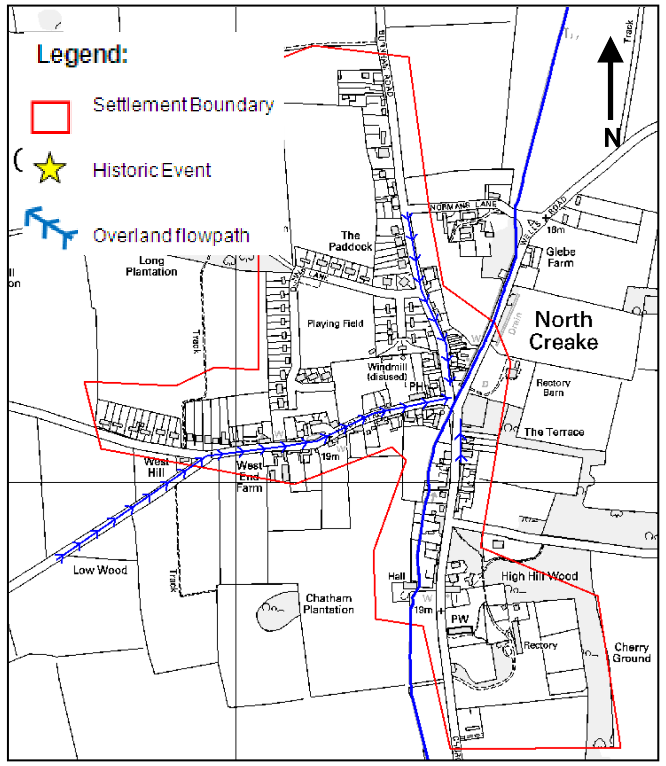
The historic flooding recorded to the west of the settlement (near the Docking Road/ Ringstead Road junction) is identified as being from overland sources and may be a result of combined overland flows and a high water table.

The settlement's drainage system is reliant on the Anglian Water pumping station. This pumping system discharges to the River Burn, therefore if the river flowing full, then the system cannot freely discharge. This can lead to the potential 'backing up' of the system. This would result in water ponding at the low point in the area, at the junction of Friars Lane and Mill Road, and may also lead to surcharging at locations through the eastern (lower) portion of the settlement.

Creake Road is poorly drained, and therefore during larger rainfall events surface water enters Burnham Market from the south. If the surface water volume is large enough, flooding will affect a garage and properties near the junction of Creake Road and Station Road. Station Road itself is also known to have poor drainage due to a lack of gullies, and therefore roof drainage discharges directly on to the road, with no attenuation provided. This in turn exacerbates the flooding problem at the junction with Creake Road.

3.7.3 North and South Creake





North Creake

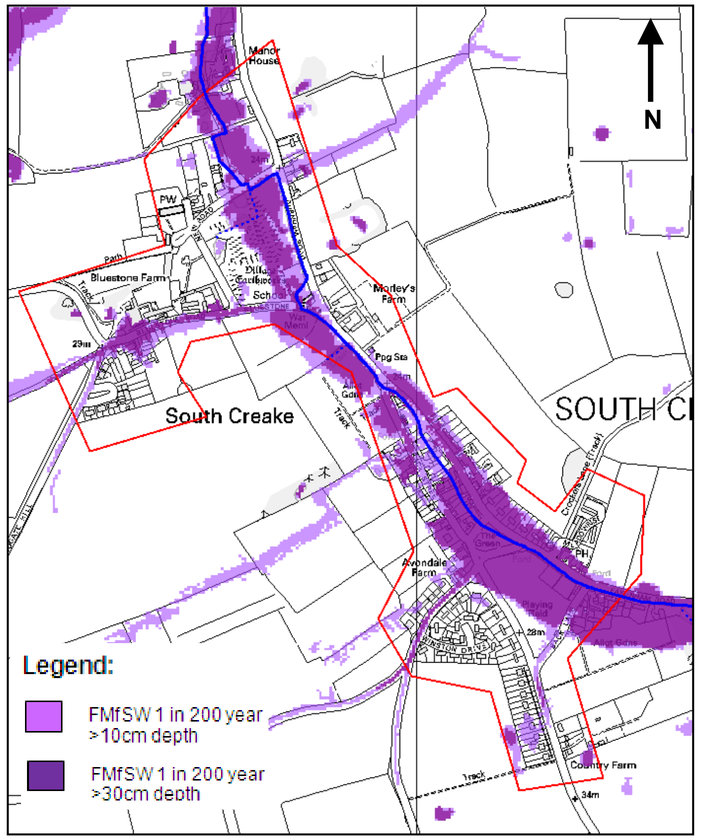
The topography of the area and FMfSW, suggest that surface water flowing from the west has the potential to flood properties within North Creake. The site inspection also found that properties in the village are discharging directly onto the road network, which may impact downhill areas. The area of greatest risk is within centre of the village, at the junction of Wells Road, West Street and Burnham Road, adjacent to the River Burn. Surface water ponding could only reach and approximate depth of 0.2m before it would spill into the River Burn. If the river was 'bank full', then the surface water flooding in the area could increase. This location is also likely to be at risk from fluvial flooding.

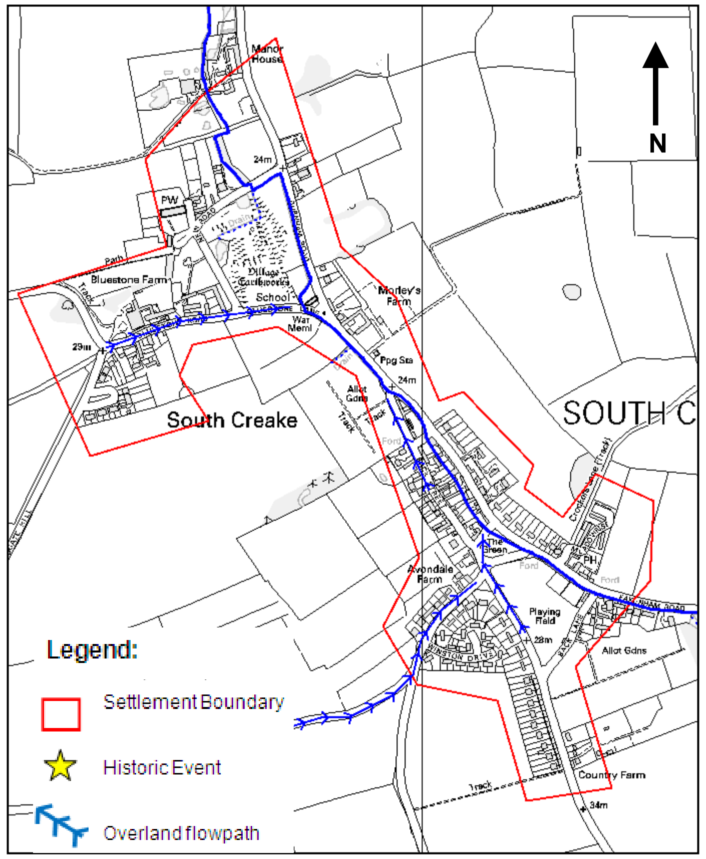
Overland flow has the potential to enter properties on Burnham Road as the doorsteps are flush with the road level. One of the properties currently has a flood gate installed, suggesting the existing problem of surface water in the area that might require further investigation.

Sewers - Anglian Water records indicate that the majority of the site utilises the foul drainage network – no pipe diameter information was available for the settlement. Excess flows will drain into the River Burn.

Pumps – there is a pump station within the north of the settlement conveys foul flows to a sewage plant near Burnham Market

Groundwater – the AStGWF northern two thirds of the settlement are identified as having a moderate risk (≥25% to <50%) of groundwater emergence, whilst the southern third is identified as being at a low (<25%) risk,





South Creake

The topography of the area and FMfSW, suggest that surface water flowing from the northwest farms may influence overland flows in the settlement. The greatest constraint to drainage would be the capacity in the River Burn, as it appears that deposition from the upper farmlands may influence the capacity of the river through the settlement.

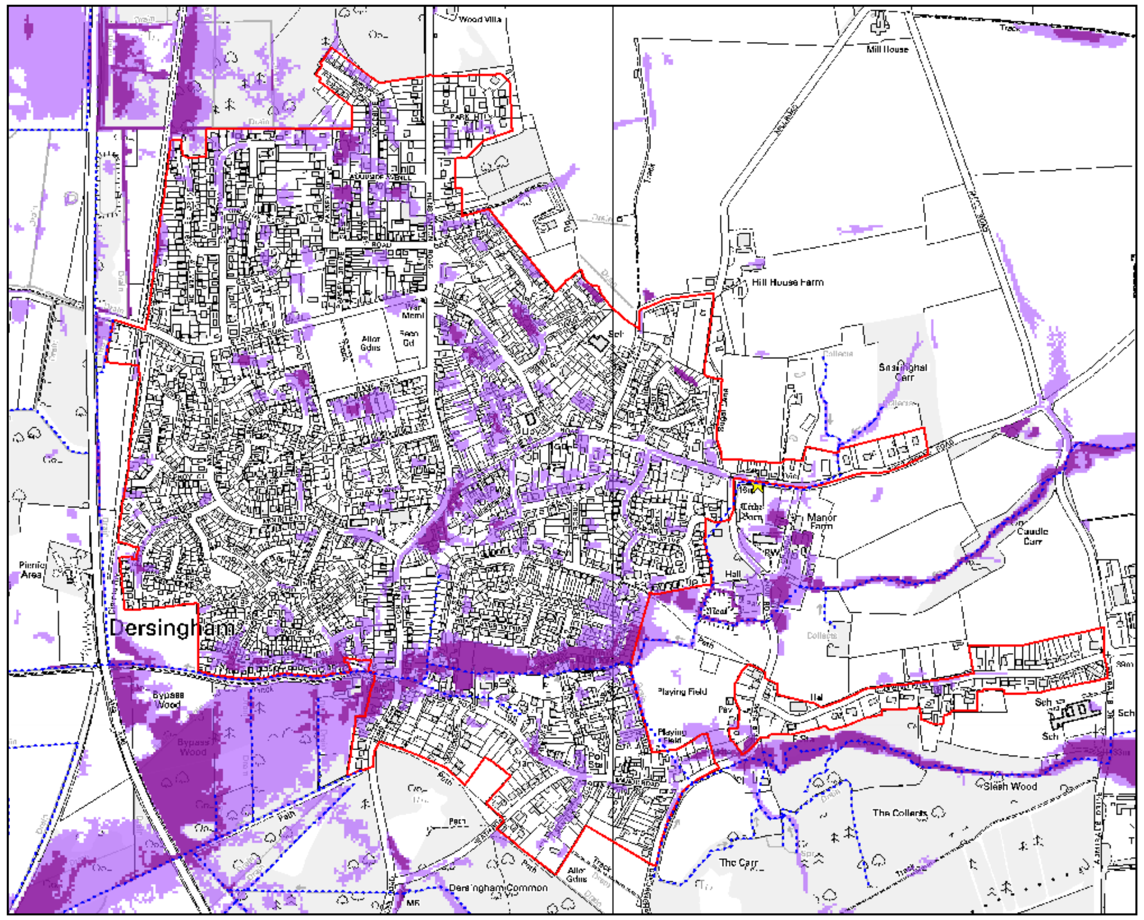
From the site inspection, it appears that the greatest risk to the settlement would be from fluvial flooding as the level of the settlement, in relation to the banks of the river, would promote the generation of on overland flowpath through the village. Any obstruction within the channel of the river could create localised flooding.

Sewers - Anglian Water records indicate that the majority of the site utilises the foul drainage network – no pipe diameter information was available for the settlement. Excess flows will drain into the River Burn

Pumps – there are two pump stations within the settlement which conveys foul flows to a sewage plant near Burnham Market.

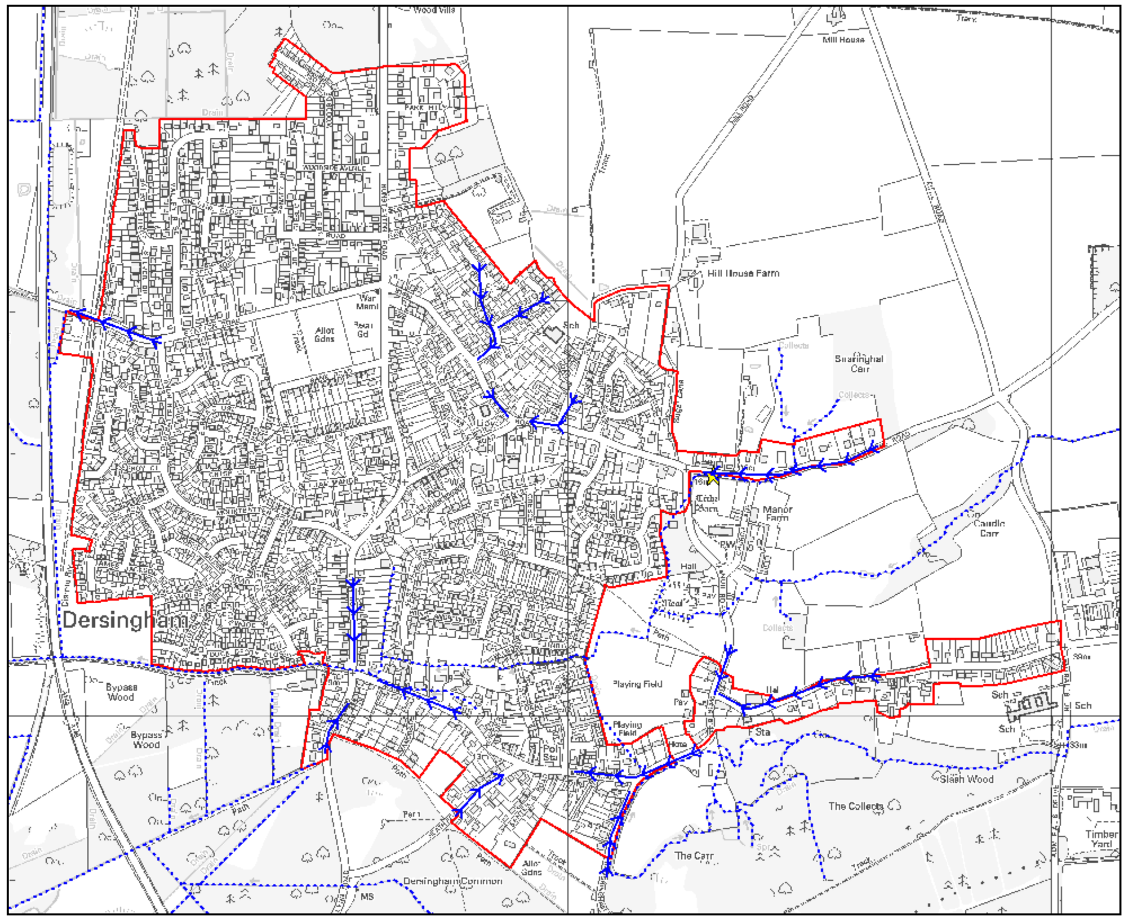
Groundwater – the AStGWF indicates that the populated areas of South Creake are identified as having a moderate risk (≥25% to <50%) of groundwater flooding.

3.7.4 Dersingham



Legend:

- Settlement Boundary
- Historic Event
- Overland flowpath
- FMfSW 1 in 200 year >10cm depth
- FMfSW 1 in 200 year >30cm depth



Sewers - the majority of the settlement utilises a separated drainage system with pipe diameters varying between 150mm-225mm with some larger pipes. Information relating to size of pipes in the eastern half of the settlement is missing.

Pumping – there are three pumping stations within the settlement which appear to be connected to the foul network.

Groundwater – a large portion of the settlement is not covered by the AStGWF maps however there are two tiles which indicate that the eastern boundary of the site is at a low risk of emergence.

General Comments:

No historic records are identified in this settlement. The site inspection determined that ponding from surcharging and overland flow may occur near the Saxon Way/Chapel Road intersection. During the site inspection standing water was present in the topographic low area (and on several manhole lids), indicating that this drainage intersection drains the 'steep' catchment to the east. Flattening out at the junction, it is likely that the system could surcharge as a result of upstream flows from the steep catchment. Upon ponding, water could spill into driveways before flowing through nearby gardens.

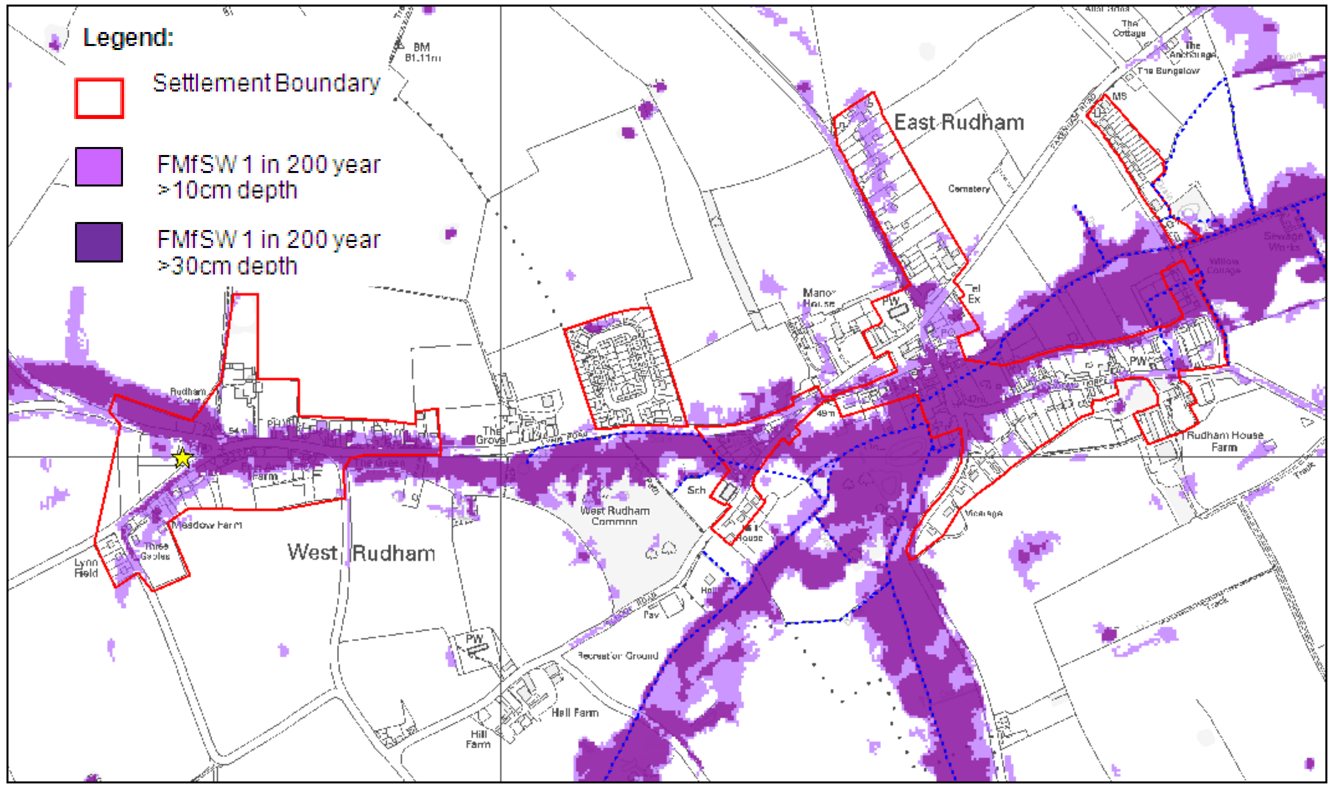
No drainage was identified within the Bank Road – if the adjacent ditch (acting as the drainage network) were to become full (by downstream or local obstruction) then runoff could flow into properties south of Bank Road into an area which is identified as a topographic low on the EA FMfSW.

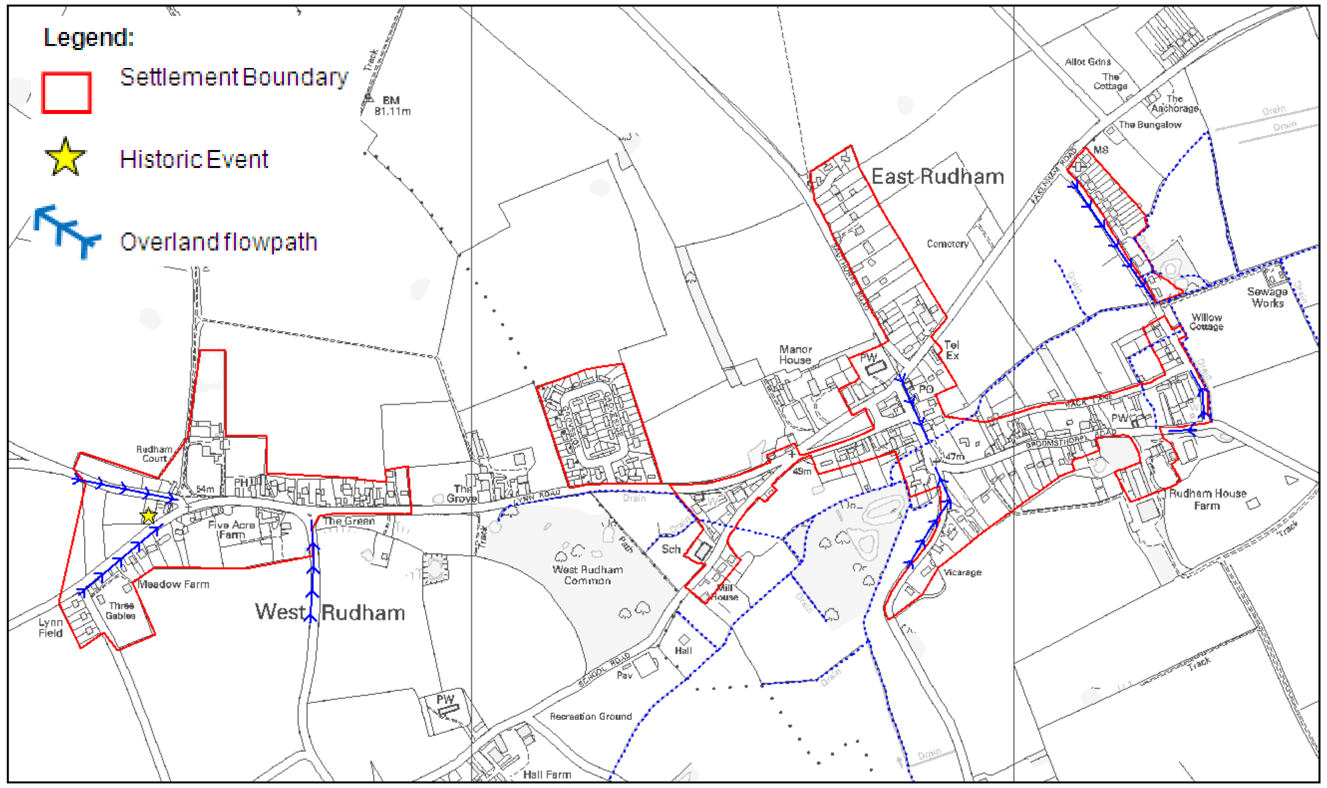
Potential flooding may occur near the following intersections with Manor Road as a result of excess overland flow being conveyed along the road:

- Shernborne Road;
- Doddshill Road; and
- Lynn Road

The SW drainage is in poor condition and undersized along roads. For instance, the road to the south is taking runoff from properties (e.g. Fire station) and the field, and it is likely that the road drainage (possibly 100mm pipe) was only designed to take rainfall falling on the road. During site visit, many gullies were blocked, and runoff was directed towards these drains from adjacent properties, and nearby fields. These roads provide a perfect opportunity for runoff to flow towards the centre of settlement and impact drainage in these areas.

3.7.5 East and West Rudham



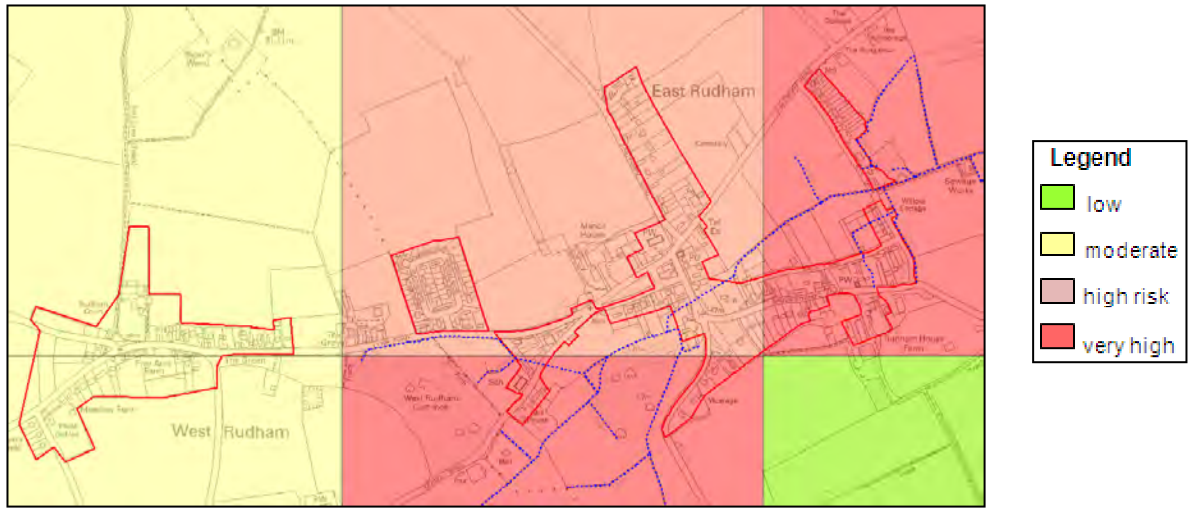


Sewers – *West Rudham* is served by 150mm – 225mm drainage pipes within a combined/foul network

East Rudham predominantly utilises 225mm pipes within some 150mm in the upstream network in the same combined/foul network drains *West Rudham*

Pumping – no pumping stations are identified within the settlement

Groundwater – Flood Risk varies within the two settlements



It appears to be lower in West Rudham and higher in East Rudham. This can be attributed to the settlements' proximity to watercourse which bisects East Rudham.

General Comments:

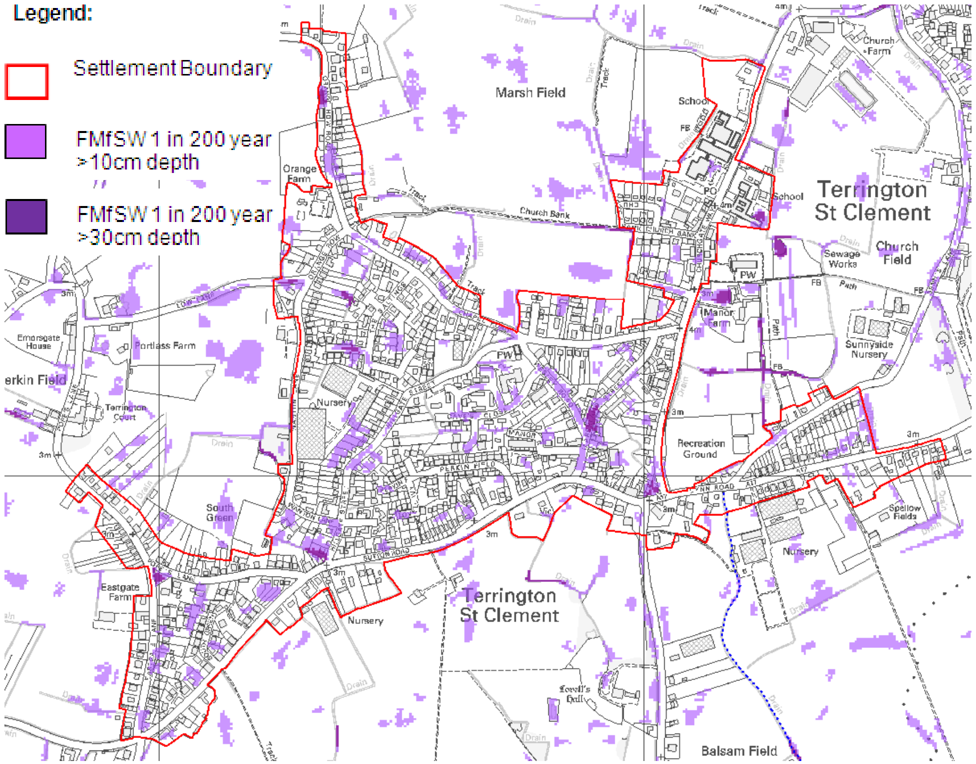
West Rudham

There is a historic record for flooding near the intersection of Lynn Road (A148) and the Mill Lane. Records indicate that this is a result of overland flow (from heavy rainfall) and the capacity of the drainage network/ditches (and possibly saturated ground conditions). This event flooded portions of the road and local properties. This was confirmed during discussion with a local resident which provided some evidence for the potential areas of ponding in the FMfSW. The local resident also indicated that a majority of the flooding on the road is a result of runoff discharging from nearby fields into the roads (which have a minimal pipe diameter to convey runoff).

East Rudham

No historic records were identified within East Rudham. Runoff (from West Rudham) that does not drain into the network within Lynn Road will be conveyed through this settlement until it discharges into the local watercourse that bisects the site. This area utilises several ditches to assist in the drainage of runoff within the settlement. This watercourse eventually discharges into the River Tat (approximately 1.8km east of the settlement). The site inspection indicates that areas of ponding may occur near the intersection of Broomsthorpe Road and Station Road as a result of the topography and drainage network.

3.7.6 Terrington St. Clement



General Comments:

No historic flood records were identified within the settlement.

It is assumed that the inclusion of the surface water drainage network within Sutton Road may be a result of a previous risk of flooding to the settlement – as the pipe size is considerably larger than the foul drainage network.

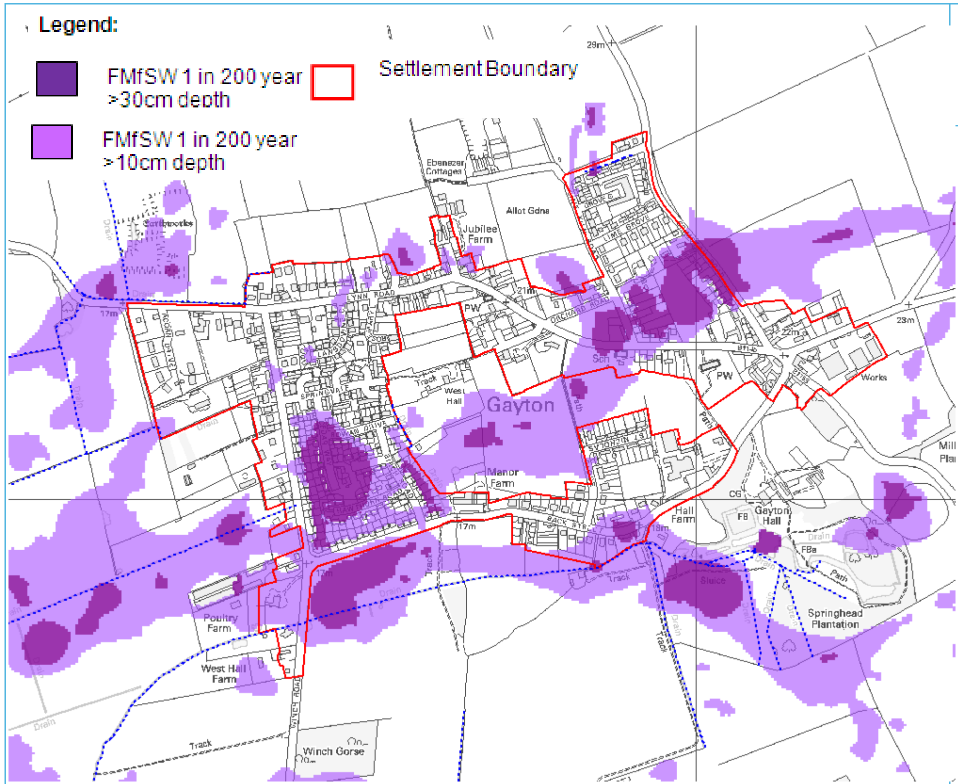
The topography of the settlement is relatively flat with no specific overland flow path being visible. Due to the limited size of the drainage network (excluding new surface water pipes) any blockage within the road gullies will lead to runoff will ponding topographic low points (e.g. Marshland Street and Wesley Road intersection).

Sewers – Anglian Water records indicate that the majority of the site utilises the foul drainage network which are typically 150mm pipes. There are several areas of surface water only pipes near Sutton Road

Pumps – there are five pumping stations within the settlement which are completely connected to the foul network.

Groundwater - settlement is not covered by the AStGWF maps however there are two tiles which indicate that the eastern boundary of the site is at a low risk of emergence. The local geology appears to be Alluvium (Clay, Silt And Sand) over Kimmeridge Clay Formation and is therefore considered at a low risk of flooding from any underground source but will alternatively not promote the infiltration of runoff within the settlement.

3.7.7 Gayton



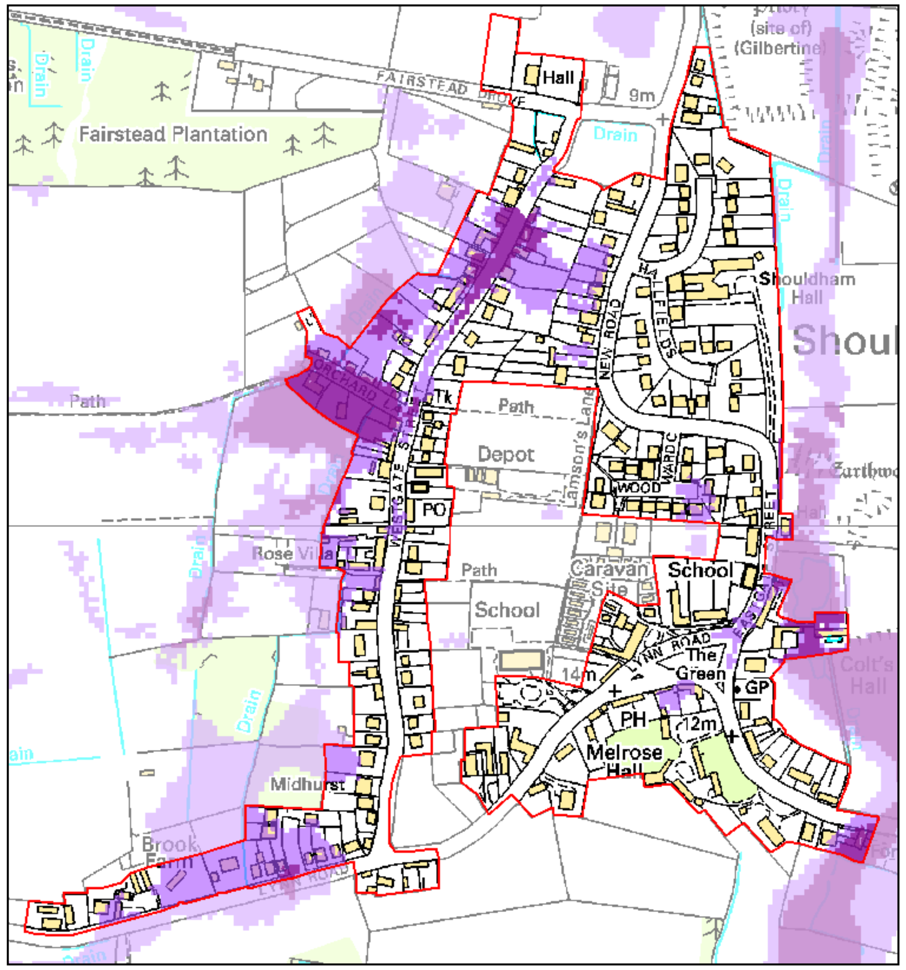
Groundwater – The settlement of Gayton appears to be at a 'high' risk (≥50% <75%) of flooding from groundwater emergence according to the EA AStGWF dataset.

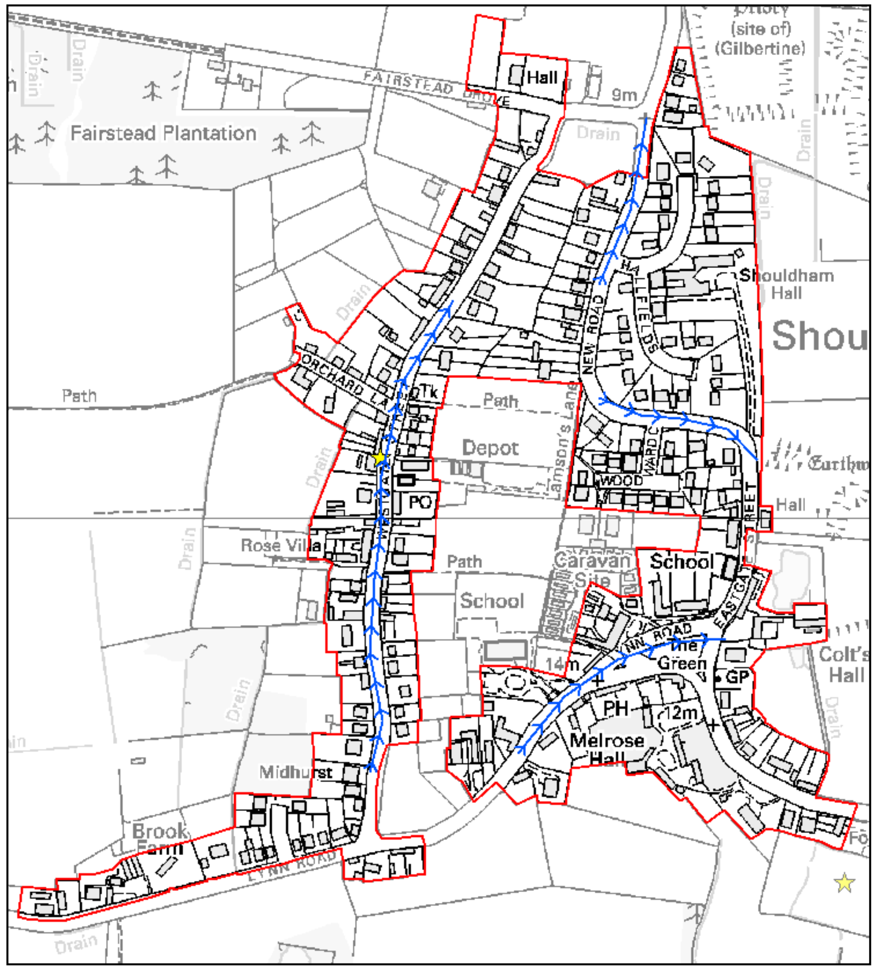
General Comments:
The FMfSW map indicates a number of low points in which surface water would pond within Gayton, also showing a flowpath through the settlement in a south-westerly direction. The site inspection confirmed that some of the field runoff (to the northeast) would be intercepted by the ditch running along Grimston Road, which would reduce the overland flow path (and predicted ponding) as shown by the FMfSW map.

Various local residents stated that Back Street has a history of surface water flood incidents, associated with the ongoing development in this part of the settlement. One resident noted regular flooding of the area with up to 0.4m of standing water and the road being impassable. The landlady of 'The Crown' recalled that the area was once occupied by natural springs – this it validated by the groundwater flood risk to the area. Another resident commented that the recent development (in the southeast of the settlement) had 'infilled' an important roadside ditch, and had worsened the situation. The site inspection was extended to this areas and it is suggested that the ditch may have been adopted as an infiltration trench to attenuate surface water runoff from the development. If this had previously been used by the local catchment and no compensation for its loss was included within the design then there is a chance that this minor change could locally increase the risk of flooding as a result of the ditch receiving a greater volume of runoff.

Sewers - No Anglian Water drainage information is available for Gayton. King's Lynn highway records indicate gullies and ditches present within the settlement, but does not specify pipe sizes. A 15m x 1m Aquacell feature is located near the Grimston Road/ Lynn Road Junction.

3.7.8 Shouldham





Legend:

- Settlement Boundary
- Historic Event
- Overland flowpath
- FMfSW 1 in 200 year >10cm depth
- FMfSW 1 in 200 year >30cm depth

Sewers:

A review of the Anglian Water sewer database indicates that the settlement utilises a foul drainage network to drain runoff. The majority of the pipe network size is unknown, however the few pipes that are identified are of a 150mm diameter.

Groundwater:

The EA ASTGWF does not highlight a risk to this settlement.

General Comments:

Two flood records have been recorded by the Environment Agency. These were located in Westgate Street and near Forresters Row (both in July 1998) as a result of excess surface water runoff overwhelming the drainage system.

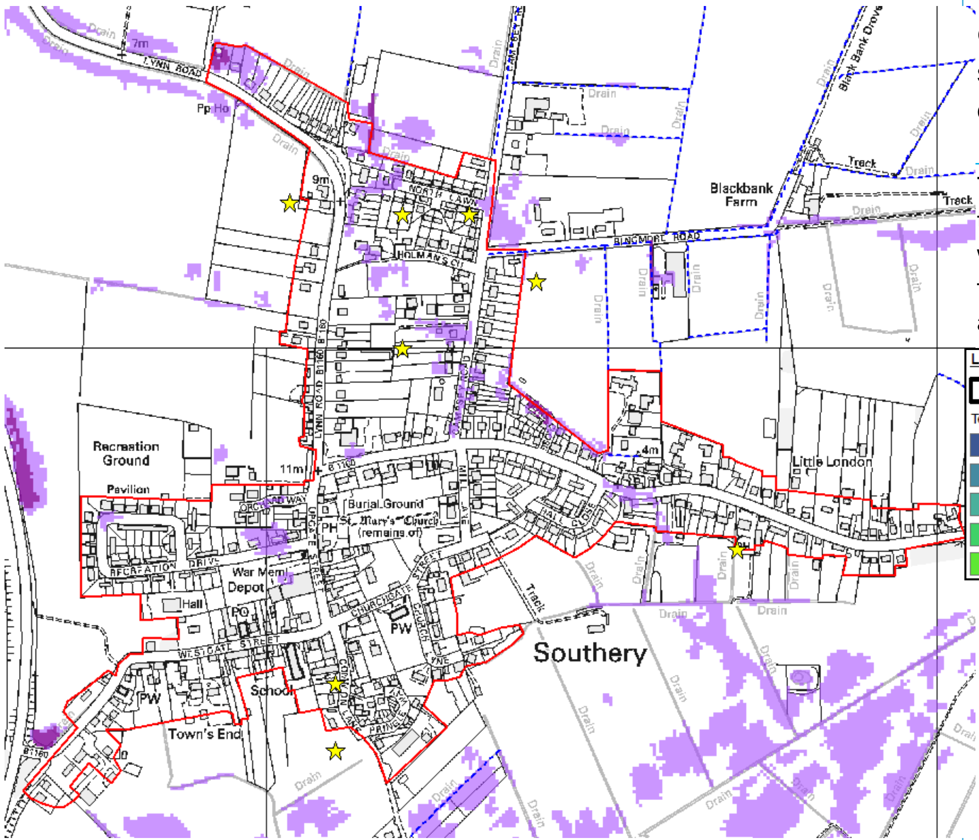
From the site inspection there are two distinctive surface water flow routes in to Shouldham. One is from Lynn Road in the south west, and the other is from the eastern open space/fields. The village appears to have generally adopted a ditch to discharge surface water runoff into, which is centrally on the northern boundary of the settlement.

Potential surface water flooding has been identified to the eastern part of the settlement adjacent to Eastgate Street and Lynn Road, due to the flat topography in the area. This area has been adopted as the discharge point for the eastern portion of the settlements drainage, but is the natural discharge location for the low-lying marsh to the east. It has been identified that this discharge area could fill during an extreme event as it would be fed by both the settlements drainage system and the saturated ground to the east. This could be problematic if two or more rainfall events occur in succession, as the drainage system could potentially back up and the water table in the nearby marsh could rise, which could lead to extensive flooding.

There is anecdotal evidence from a local resident, and an IDB representative, suggesting that the condition of the drainage system in the southeast (in the vicinity of the discharge area) of Shouldham is poor. It was also reported that the headwall (within the discharge) area is close to collapsing due to its poor condition. These discussions also identified that a road gully near Forrester's Row is regularly blocked resulting in surface water ponding in the road.

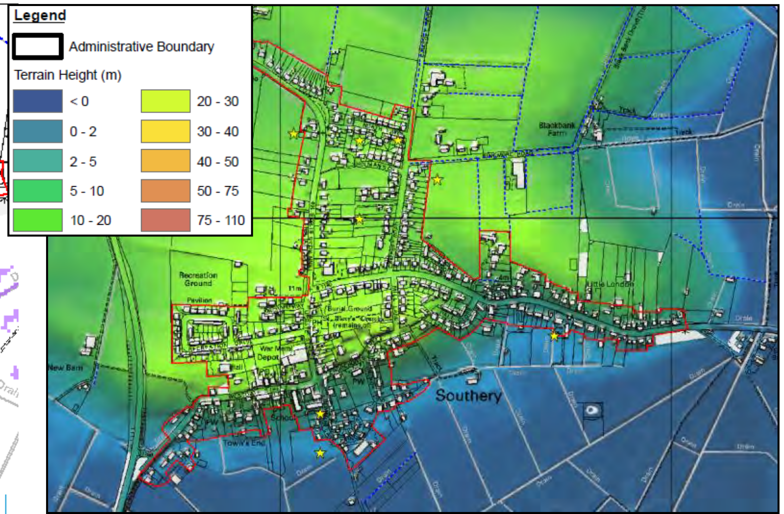
Flooding along the road in the west of Shouldham is assumed to be a result of poor road-side drainage, with locals indicating that the road gullies regularly blocked. If upstream overland flows were unable to drain via the gullies, this area could potentially reach flood depths of up to 0.4m (due to the natural topography). Surface water would fill depressions in the road, spilling towards northern junction of Fairstead Drove and Westgate Street. No properties appear to be at risk in this area as they are located above the likely flood threshold level, resulting only in the road flooding. There is potential for a pluvial-fluvial flooding interaction at the northern junction due to a small freeboard of the road above the watercourse.

3.7.9 Southery



Groundwater – The EA AStGWF maps indicate that the settlement is at a low (< 25%) risk of groundwater emergence.

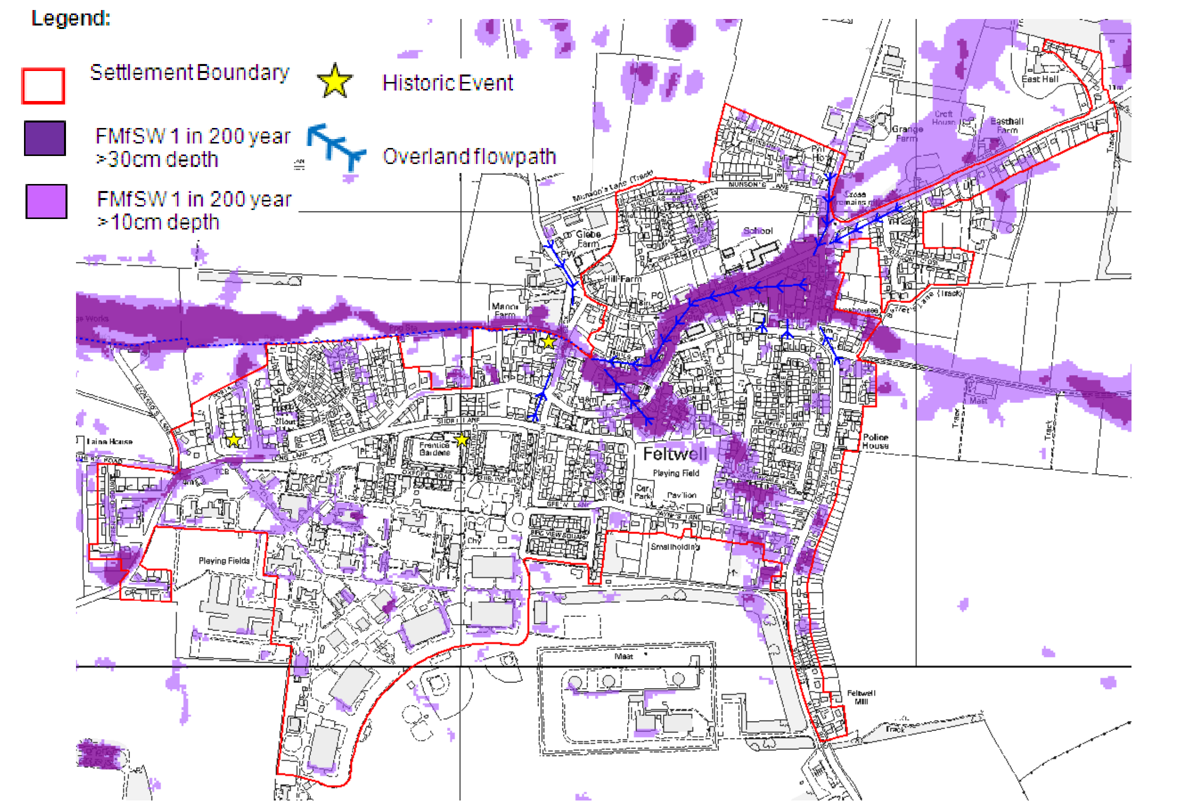
The settlement has nine flood records within the settlement and two located just south of the settlement towards the sewage works. These incidents relate to bankfull dikes, infrastructure failure, surcharging manholes or drainage work which have not alleviated an existing flood risk.



Sewers - No Anglian Water drainage information is available for Southery. King's Lynn highway records indicate gullies and ditches present within the settlement, but do not specify pipe sizes or their direction.

A review of the local topography indicates that the settlement appears to be on higher ground and the head of the local drainage catchments. Southery's location reduces the risk of surface water flooding from the local catchment as the greatest risk within the settlement would be a result of local 'sag' points in the road or undersized infrastructure.

3.7.10 Feltwell



Sewers - Anglian Water drainage information indicates that the settlement utilises a combined foul network but does not indicate and pipe size information with only a few 150mm being identified.

Pumping - one pumping station is located within the settlement which diverts runoff into the sewage works before discharging runoff from it (and the nearby watercourse) into the 'Cut-Off Chanel'.

Groundwater – The settlement of Feltwell appears to be at a 'very high' risk (≥75%) of flooding from groundwater emergence according to the EA AStGWF dataset.

General Comments:

There have been three historic records of flooding within the settlement relating to surface water. Two of these are located within areas that appear to be within natural topographic flowpaths.

An area in the centre of the settlement has been highlighted as being at risk of potential surface water flooding. The area is located within a natural valley, with housing and gardens located below the surrounding roads. Therefore, if the road drainage system is overwhelmed surface water would flow over land into these gardens and pond, potentially flooding the properties. Depending upon the severity of the event, surface water would then flow overland to the west between the gardens. Historic surface water flooding has been recorded at a low-lying spot on Short Beck and it is noted that flooding probably occurred as a result of the flooding regime described above.

There is no drainage information available for the Royal Air Force base. Uncontrolled flows from this area (and other upstream catchment areas) may increase the risk of flooding in the settlement as a result of the topography and urbanising the natural valley.

3.7.11 Risk to Future Development

As discussed in Section 1.8, a number of sites will be identified for future development through Site Allocation Plans. It is therefore important that surface water flood risk identified within the report should be a consideration in the Site Allocation Plans.

3.7.12 Effect of Climate Change

The effect of climate change on surface water flood risk has also been analysed through the risk assessment phase of this study. Based on current knowledge and understanding, the effects of future climate change are predicted to increase the intensity and likelihood of summer rainfall events, meaning surface water flooding may become more severe and more frequent in the future.

To analyse what impact this might have on flood risk across the Borough in the future, the surface water model was run for a 1 in 100 year probability event (1% AEP) to include the effect of climate change. Based on current guidance (taken from Table B.2 of PPS25) an increase in peak rainfall intensity of 30% was assumed for this model scenario.

The depth grids for these model runs are included in Appendix C along with the other mapped outputs from the modelling process.

PHASE 3: OPTIONS

4 Options Assessment Methodology

4.1 Objectives

Phase 3 provides the methodology for undertaking a high level options assessment (if CDAs are determined at a later stage) and indicates what options are generally available for reducing flood risk within the Borough. This involves identifying a range of structural and non-structural options for alleviating flood risk in the Borough, and assessing the feasibility of these options. As well as surface water, consideration must be given to other sources of flooding and their interactions with surface water flooding, with particular focus on options which will provide flood alleviation from combined flood sources.

The next purpose of this phase of work is to typically assess and shortlist options in order to eliminate those that are not feasible or cost beneficial. Options which are not suitable are discarded and the remaining options are developed and tested against their relative effectiveness, benefits and costs. Measures which achieve multiple benefits, such as water quality, biodiversity or amenity, should be encouraged and promoted. The target level of protection is typically set as the 1 in 75 year probability event (1.3% AEP); this will allow potential solutions to be aligned with the current level of insurance cover which is available to the public.

The flow chart below (Figure 4-1) presents the process of identifying and short-listing options that have been identified as part of the Phase 3.

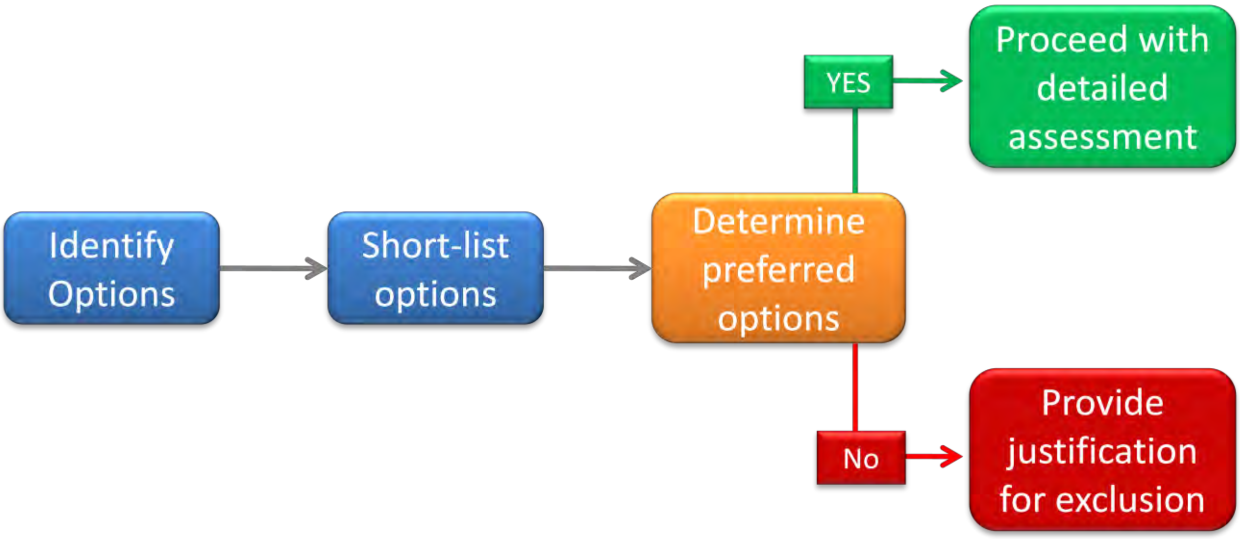


Figure 4-1 Process of identifying and short-listing options and measures [adapted from Defra SWMP Guidance]

To maintain continuity within the report and to reflect the flooding mechanisms within the study area, the options identification should take place on an area-by-area basis following (the process established in Phase 2). Therefore, the options assessment undertaken as part of the SWMP identifies the options which are applicable to the Borough as a whole. It is therefore important that consideration is given to reducing the risk in the un-modelled settlements through the implementation of measures across the whole study area.

The options assessment presented here follows the methodology described in the Defra SWMP Guidance, but is focussed on highlighting areas for further analysis and immediate 'quick win' actions.

4.2 Links to Funding Plans

It is important to consider local investment plans and initiatives and committed future investment when identifying measures that could be implemented within the Borough.

The following schemes could provide linked funding solutions to flood alleviation work in the Borough, which would provide a cost effective and holistic approach to surface water flood risk management:

- Local Green Infrastructure Delivery Plans;
- Local Investment Plan and Programme (funding plan for delivery of the LDF);
- Major commercial and housing development is an opportunity to retro-fit surface water management measures (housing associations and private developers);
- Norfolk County Council highways department investment plans; and
- Anglian Water Business Plan (& PR14).

4.3 Options Identification

The Defra SWMP Technical Guidance defines measures and options as:

> *"A measure is defined as a proposed individual action or procedure intended to minimise current and future surface water flood risk or wholly or partially meet other agreed objectives of the SWMP. An option is made up of either a single, or a combination of previously defined measures."*

This stage aims to identify a number of measures and options that have the potential to alleviate surface water flooding across the Borough. It has been informed by the knowledge gained as part of the Phase 1 and Phase 2 assessment. Where possible, options have been identified with multiple benefits such as also alleviating flooding from other sources. At this stage the option identification pays no attention to constraints such as funding or delivery mechanisms to enable a robust assessment.

The options assessment considers all types of options including[5]:

- Options that change the source of risk;
- Options that modify the pathway or change the probability of flooding;
- Options that manage or modify receptors to reduce the consequences;
- Temporary as well as permanent options;
- Options that work with the natural processes wherever possible;
- Options that are adaptable to future changes in flood risk;
- Options that require actions to be taken to deliver the predicted benefits (for example, closing a barrier, erecting a temporary defence or moving contents on receiving a flood warning);
- Innovative options tailored to the specific needs of the project; and,
- Options that can deliver opportunities and wider benefits, through partnership working where possible.

[5] Environment Agency (March 2010) *'Flood and Coastal Flood Risk Management Appraisal Guidance',* Environment Agency: Bristol.

4.4 Identifying Measures

Surface water flooding is often highly localised and complex. There are few solutions which will provide benefits in all locations, and therefore, its management is largely dependent upon the characteristics of the CDA. This section outlines potential measures which have been considered for mitigating the surface water flood risk within the Borough.

The SWMP Plan Technical Guidance (Defra 2010) identifies the concept of Source, Pathway and Receptor as an appropriate basis for understanding and managing flood risk. Figure 4-2 identifies the relationship between these different components, and how some components can be considered within more than one category.

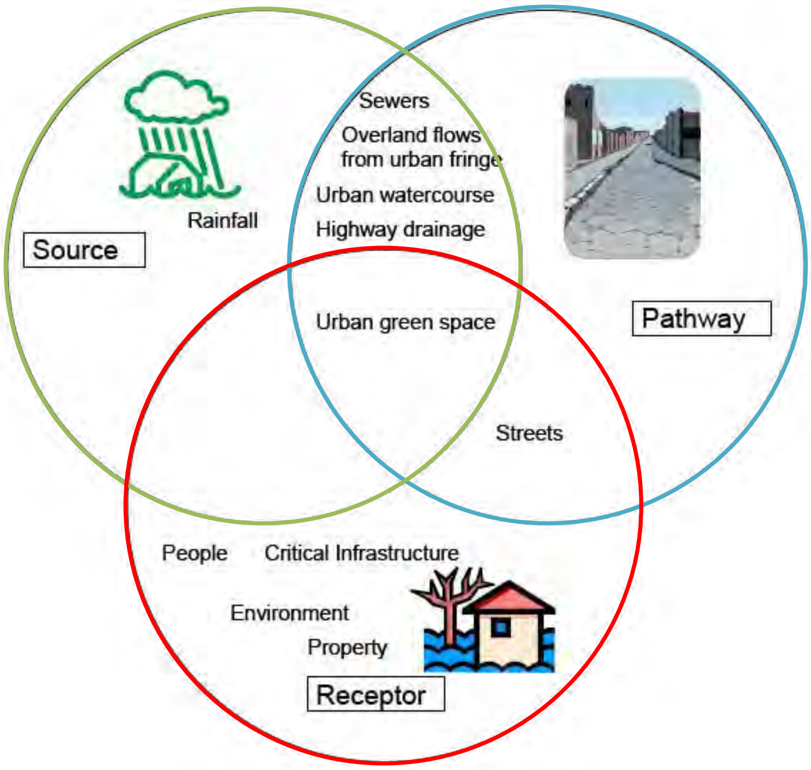


Figure 4-2 Illustration of Sources, Pathways & Receptors (extracted from SWMP Technical Guidance, Defra 2010)

When identifying potential measures, it is useful to consider the source, pathway, receptor approach (refer to Figure 4-2 and Figure 4-3). Both structural and non-structural measures should be considered in the optioneering exercise undertaken for future CDAs. Structural measures can be considered as those which require fixed or permanent assets to mitigate flood risk (such as a detention basin, increased capacity pipe networks). Non-structural measures may not involve fixed or permanent facilities, and the benefits to of flood risk reduction is likely to occur through influencing behaviour (education of flood risk and possible flood resilience measures, understanding the benefits of incorporating rainwater reuse within a property, planning policies etc).

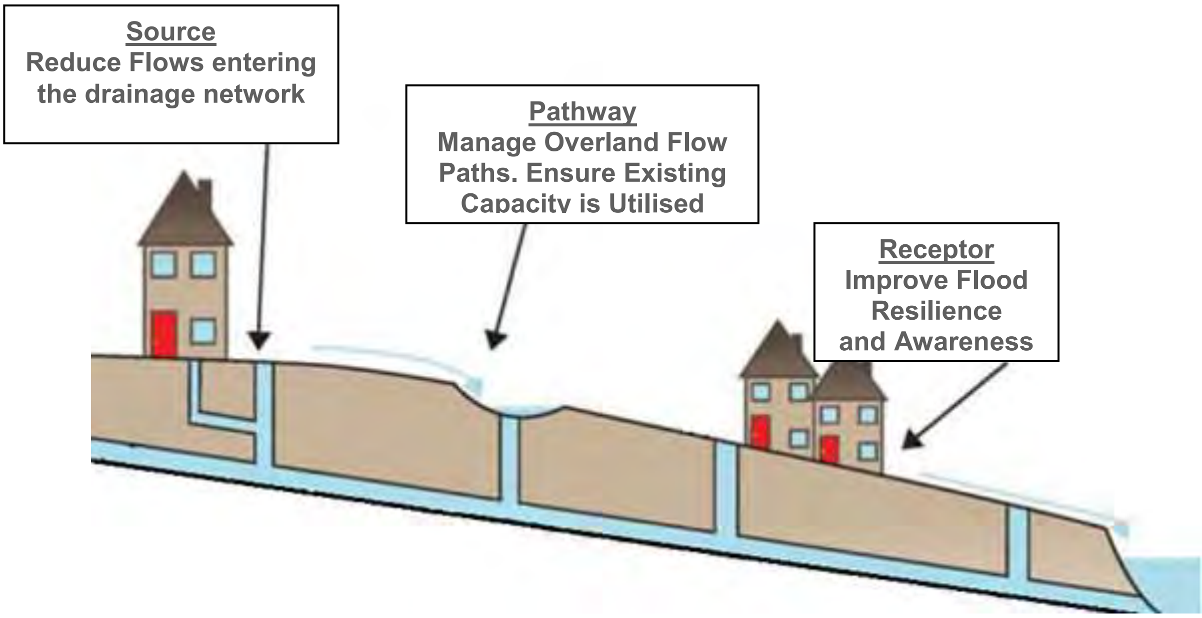


Figure 4-3 Source, Pathway and Receptor Model (adapted from Defra SWMP Technical Guidance, 2010)

Methods for managing surface water flooding can be divided into methods which influence either the Source, Pathway or Receptor, as described below, (refer to Table 4-1, overleaf.):

- Source Control: Source control measures aim to reduce the rate and volume of surface water runoff through increasing infiltration or storage, and hence reduce the impact on receiving drainage systems. Examples include retrofitting SuDS (e.g. bioretention basins, wetlands, green roofs etc) and other methods for reducing flow rates and volume.

- Pathway Management: These measures seek to manage the overland and underground flow pathways of water in the urban environment, and include: increasing capacity in drainage systems; separation of foul and surface water sewers etc.

- Receptor Management: This is considered to be changes to communities, property and the environment that are affected by flooding. Mitigation measures to reduce the impact of flood risk on receptors may include improved warning and education or flood resilience measures.

Table 4-1 Typical Surface Water Flood Risk Management Measures

	Generic measures	Site specific measures
	• Do Nothing (do not continue maintenance) • Do Minimum (continue current maintenance)	
Source control	• Bioretention carpark pods • Soakaways, water butts and rainwater harvesting • Green roofs • Permeable paving • Underground storage; • Other 'source' measures	• Swales • Detention basins • Bioretention basins; • Bioretention carpark pods; • Bioretention street planting; • Ponds and wetlands
Pathway Management	• Improved maintenance regimes • Increase gulley assets	• Increase capacity in drainage system • Separation of foul & surface water sewers • Managing overland flows • Land Management practices • Other 'pathway' measures
Receptor Management	• Improved weather warning • Planning policies to influence development • Social change, education and awareness • Improved resilience and resistance measures • Raising Doorway/Access Thresholds • Other 'receptor' measures	• Temporary or demountable flood defences - collective measure

4.5 Identifying Options

Following the identification of a number a measures (as described in Table 4-1 above), a series of Borough-wide options were defined based on this assessment. These options were based initially on a range of options (scheme categorisations) identified in Table 4-2. Each of the standard measures (from Table 4-1) have been categorised within an option.

Table 4-2: Potential options

Description		Standard Measures Considered
Do Nothing	Make no intervention / maintenance	• None
Do Minimum	Continue existing maintenance regime	• None
Improved Maintenance	Improve existing maintenance regimes e.g. target improved maintenance to critical points in the system.	• Improved Maintenance Regimes • Other 'Pathway' Measures
Planning Policy	Use forthcoming development management policies to direct development away from areas of surface water flood risk or implement flood risk reduction measures.	• Planning Policies to Influence Development

Description		Standard Measures Considered
Source Control, Attenuation and SUDS	Source control methods aimed to reduce the rate and volume of surface water runoff through infiltration or storage, and therefore reduce the impact on receiving drainage systems.	• Green roofs • Soakaways • Swales • Permeable paving • Rainwater harvesting • Detention Basins • Ponds and Wetlands • Land Management Practices • Other 'Source' Measures
Flood Storage / Permeability	Large-scale SuDS that have the potential to control the volume of surface water runoff entering the urban area, typically making use of large areas of green space. Upstream flood storage areas can reduce flows along major overland flow paths by attenuating excess water upstream, which reduce the demands on downstream networks.	• Detention Basins • Ponds and Wetlands • Managing Overland Flows (Online Storage) • Land Management Practices • Other 'Source' Measures • Other 'Pathway' Measures
Separate Surface Water and Foul Water Sewer Systems	Where the settlement is served by a combined drainage network separation of the surface water from the combined system should be investigated. In growth areas separation creates capacity for new connections.	• Separation of Foul and Surface Water Sewers
De-culvert / Increase Conveyance	De-culverting of watercourses and improving in-stream conveyance of water.	• De-culverting Watercourse(s) • Other 'Pathway' measures
Preferential / Designated Overland Flow Routes	Managing overland flow routes through the urban environment to improve conveyance and routing water to watercourses or storage locations.	• Managing Overland Flows (Preferential Flowpaths) • Temporary or Demountable Flood Defences • Other 'Pathway' measures
Community Resilience	Improve community resilience and resistance of existing and new buildings to reduce damages from flooding, through, predominantly, non-structural measures.	• Improved Weather Warning • Temporary or Demountable Flood Defences • Social Change, Education and Awareness • Improved Resilience and Resistance Measures • Other 'Receptor' Measures
Infrastructure Resilience	Improve resilience of critical infrastructure in the settlements that are likely to be impacted by surface water flooding e.g. electricity substations, pump houses.	• Improved Resilience and Resistance Measures • Other 'Receptor' Measures
Other - Improvement to Drainage Infrastructure	Add storage to, or increase the capacity of, underground sewers and drains and improving the efficiency or number of road gullies.	• Increasing Capacity in Drainage Systems • Other 'Pathway' measures
Other or Combination of Above	Any alternative options that do not fit into above categories and any combination of the above options where it is considered that multiple options would be required to address the surface water flooding issues.	

4.6 Options Assessment Guidance

Unless a detailed appraisal of cost and benefits of every measure is undertaken, a high-level scoring system for each of the options can be utilised to short-list preferred options. The approach to short-listing options is based on the guidance in FCERM and Defra's SWMP guidance. The scoring criteria are provided in Table 4-3.

Table 4-3: Options assessment short-listing criteria

<table>
<tr><th>Criteria</th><th>Description</th><th>Score</th></tr>
<tr><td>Technical</td><td>• Is it technically possible and buildable?
• Will it be robust and reliable?
• Would it require the development of new techniques in order to be implemented?</td><td rowspan="5">U: Unacceptable (measure eliminated from further consideration)

-2: High negative outcome

-1: Moderate negative outcome

0: Neutral

+1: Moderate positive outcome

+2: High positive Outcome</td></tr>
<tr><td>Economic</td><td>• Will the benefits exceed the cost?
• Is the option within the available budget / funding? (This will depend on available funding, although it must be remembered that alternative routes of funding could be available)</td></tr>
<tr><td>Social</td><td>• Will the community benefit from the option?
• Does the option have benefits for local amenity?
• Does the option result in any objection from local communities?</td></tr>
<tr><td>Environmental</td><td>• Will the environment benefit from the option?
• Will the option provide benefits to water quality or biodiversity?</td></tr>
<tr><td>Objectives</td><td>• Does it help achieve objectives of SWMP partnership?
• Does the option meet the overall objective of alleviating flood risk?</td></tr>
</table>

Table 4-4 provides and example of applying the options scoring system on a Borough wide assessment.

Any agreed short-listed options can been taken forward for further assessment, possibly detailed modelling if necessary, including an overview assessment of costs, benefits and feasibility. These include the 'Do Nothing' (no intervention and no maintenance) and 'Do Minimum' (continuation of current practice) options which, in line with the Project Appraisal Guidance (PAG), should be taken forward to the detailed assessment stage (even though they might not offer the desired results).

In the event of any future proposed options, it is recommended that an Options Workshop is held with stakeholders to discuss and agree the short-listed options across within the Borough. The process is aimed at ensuring that inappropriate measures are eliminated early in the process to avoid investigation of options that are not acceptable to stakeholders. Community workshops should also be held to allow local residents, in key risk areas, to attend and find out about proposed mitigation measures.

Table 4-4: Summary of options assessment

Area /CDA	Option Category	Option Description	Options Assessment							Summary of Scheme
			Technical	Economic	Social	Environmental	Objectives	Overall	Take Forward?	
King's Lynn and West Norfolk-wide (all areas 'at risk')	Do nothing	Do nothing	-	-	-	-	-	-	✓	Make no intervention or maintenance – no benefit to area
	Do minimum	Do minimum	-	-	-	-	-	-	✓	Continue existing maintenance regimes – minimal benefit and (currently) does not include increased maintenance for the predicted increase in rainfall as a result of climate change.
	Planning Policy	Adapt spatial planning policies	2	2	1	0	2	7	✓	Adapt spatial planning policy for all new developments, especially within areas identified at high risk of surface water flooding.
	Improved Maintenance	Improved maintenance of drainage network	2	1	2	1	1	7	✓	Improved and targeted maintenance of the drainage network to avoid potential blockages which would reduce the drainage network capacity. Suggest list of targeted areas (i.e. areas at highest risk within the LFRZs or future CDAs) to focus on.
	Community Resilience	Improve community resilience to reduce damages from flooding	2	1	2	0	1	6	✓	Improve community resilience to flooding through establishing a flood warning system, reviewing emergency planning practices and encouraging the installation of individual property protection measures (such as flood-gates).
	Source Control, Attenuation and SuDS	Install rainwater harvesting systems water-butts, and bioretention features	2	2	1	1	2	8	✓	Install rainwater harvesting systems, bioretention systems and water-butts in key risk areas in order to reduce the rate and volume of surface water runoff. Upstream attenuation via wetlands and ponds could also be considered.
	Flood Storage / Permeability	Install permeable paving in key areas	2	2	1	1	2	8	✓	Install permeable paving systems in key areas and along key overland flow paths in order to reduce local runoff.
	Improvement to Drainage Infrastructure	Improve drainage network capacity within key risk areas	2	1	0	0	2	5	✓	Work collaboratively with Anglian Water to assess the possibility of increasing sewer network capacity in key areas (or those identified as having poor capacity.

Area /CDA	Option Category	Option Description	Options Assessment: Technical	Economic	Social	Environmental	Objectives	Overall	Take Forward?	Summary of Scheme
	Preferential Overland Flow Routes	Increase kerb heights and/or lower road levels along key flow paths	2	1	2	1	1	7	✓	Investigate the potential of increasing footpath heights and/or lowering road levels along key flow paths in order to retain flood water within the roads and channel it away from properties at risk of flowing.
	Other	Hydrometric monitoring	2	2	0	1	2	7	✓	Install hydrometric monitoring equipment in order to gain a better understanding of rainfall patterns and mechanisms that lead to localised flooding across the Borough.
	Other	Community Awareness	2	2	2	0	1	7	✓	Increase awareness of flooding within communities at risk through the use of newsletters, drop-in workshops, websites and social media.

5 Proposed Surface Water Drainage Policy

5.1 Borough Wide Policy

CDAs (in this instance LFRZs) delineate the areas where the impact of surface water flooding is expected to be greatest, it is acknowledged that the CDAs (and LFRZs) do not account for all the areas that could be affected by surface water flooding. It is therefore recommended that the Borough implement policies which will reduce the risk from surface water flooding throughout the whole borough, that Norfolk County Council also implement similar policies, so that both authorities promote and apply Best Management Practises to the implementation of SuDS and the reduction of runoff volumes.

The SWMP Action Plan (discussed in Section 7.1), which is a major output of this project, recommends that the following policies are implemented within the boundaries of the catchment to reduce the flood risk therein:

Policy 1: *All developments across the catchment (excluding minor house extensions less than 50m^2) which relate to a net increase in impermeable area are to include at least one 'at source' SuDS measure (e.g. water butt, rainwater harvesting tank, bioretention planter box etc). This is to assist in reducing the peak volume of runoff discharging from the site.*

Policy 2: *Proposed 'brownfield' redevelopments of more than one property or area greater than 0.1 hectare are required to reduce post-development runoff rates for events up to and including the 1 in 100 year return period event with an allowance for climate change (in line with PPS25 and UKCIP guidance) to 50% of the existing site conditions. If this results in a discharge rate lower than the Greenfield conditions it is recommended that the Greenfield rates (calculated in accordance with IoH124[6]) are used.*

Policy 3: *Developments located in Critical Drainage Areas (CDAs), Local Flood Risk Zones (LFRZs) and for redevelopments of more than one property or area greater than 0.1 hectare should seek betterment to a Greenfield runoff rate (calculated in accordance with IoH124). It is recommended that a SuDS treatment train is utilised to assist in this reduction.*

The Councils may also wish to consider the inclusion of the following policy to manage the pollutant loads generated from proposed development applications:

Policy 4: *Best Management Practices (BMP) are required to be demonstrated for development applications greater than 0.1 hectare within the catchment. The following load-reduction targets must be achieved when assessing the post-developed sites SuDS treatment train (comparison of unmitigated developed scenario versus developed mitigated scenario):*

- 80% reduction in Total Suspended Sediment (TSS);

- 45% reduction in Total Nitrogen (TN);

- 60% reduction in Total Phosphorus (TP); and

- 90% reduction in litter (sized 5mm or greater).

[6] Defra/Environment Agency, September 2005, Flood and Coastal Defence R&D Programme: Preliminary Rainfall Runoff Management for Developments (R&D Technical Report W5-074/A/TR/1 Revision D)

The Councils may also wish to consider specific policy relating to site based flood risk assessments for surface water that is similar to the current practice of the EA for fluvial flood risk. The flood risk maps produced as part of the SWMP can be used to trigger the need for a Flood Risk Assessment under Planning Policy Statement 25 for Development and Flood Risk (PPS25). The level of assessment required could be implemented in a similar fashion to the EA Flood Zones:

- 100yr Surface Water Flood Depth >0.5m = Assessment similar to EA Flood Zone 3
- 100yr Surface Water Flood Depth between 0.1 and 0.5m = Assessment similar to EA Flood Zone 2

Implementation of this policy is beyond the scope of this SWMP document and an action has been included in the Action Plan for the Borough to undertake internal consultation with their and spatial planning and development compliance staff to determine how this type of policy could be implemented.

6 Preferred Options

Following consultation with the SWMP Client Task Group and relevant stakeholders, a number of preferred options have been identified for the Borough. A range of preferred options have been identified to help alleviate surface water flood risk alongside further investigations and studies that both Norfolk County Council (as the LLFA) and the Borough should look to take forward. These are all identified in the Action Plan and ranked as high, medium and low priority actions with a long, medium or short timescale for implementation.

6.1 King's Lynn and West Norfolk Wide Options

Adaptation of spatial planning policy: Spatial planning policies (such as those being drafted for Development Management or Sites Allocations DPDs) should be adapted to reflect the outputs and findings of the SWMP study. It is recommended that emphasis is placed on the requirement for appropriate measures to reduce surface water runoff, and the requirement for FRAs to inform the detailed design of new development, particularly within those areas that have been identified at high risk of surface water flooding. This may include mitigation measures, such as SuDS, where these are appropriate. This will ensure that any redevelopment or new development does not negatively contribute to the surface water flood risk of other properties and that appropriate measures are taken to ensure flood resilience of new properties and developments in surface water flood risk areas.

Improve maintenance of the drainage network: Drainage maintenance schedules should be evaluated to reflect the findings of this study. The potential for blockages in the drainage network would exacerbate surface water flooding; this would be a particular issue in all the areas identified as being at risk of surface water flooding during an extreme event. It is recommended that a risk-based approach is applied so that drainage infrastructure in key areas is kept clear and maintained.

Despite overall funding cuts, by targeting key areas for more frequent and comprehensive maintenance while reducing maintenance in other areas, overall cost savings will be achieved in addition to reducing the chance of blockages in key areas.

Plans should be put in place to warn residents of when the gullies (and land drains/swales) are due to be cleaned and request that cars are parked elsewhere.

Improve drainage network capacity: A key recommendation of this study is to look at improving the drainage network capacity across the Borough, especially within areas that may have capacity issues.

It is recommended that work is carried out in collaboration with Anglian Water and the IDBs to assess the possibility of upgrading the network capacity in these key areas, which would reduce the risk of surface water flooding in these areas.

Improve community resilience: It is recommended that a general approach to improving community resilience is adopted across the study area, particularly in areas that have been identified as being at risk. This should include establishing a flood warning system and improving emergency planning procedures (described in more detail below) as well as encouraging property resilience through the installation of individual property protection measures, such as raising property thresholds or installing flood gates or air brick covers.

Options for funding of property protection measures should also be investigated, including the possibility of offering grants or subsidies for individual properties who are interested in installing such measures.

Improve flood warning systems: Installation of rainfall monitoring systems in key areas, in and around the study area, will provide an evidence base for flooding trigger levels and could provide data for a localised flood warning system. Providing a warning to key council operational departments and emergency services will enable the preparation and implementation of the Council's flood incident management strategy. Relaying this information to households and businesses before a large rainfall event could be achieved through text messages or phone calls warning of potential flooding, as the Environment Agency currently do with their fluvial flood alert system. This, with prior education, will allow individuals to respond with appropriate actions and measures.

Emergency planning (flood incident management): Reviewing the emergency planning procedures in areas at risk from surface water flooding will help to ensure the safety of people and to develop additional planning where required.

Due to the rapid nature of surface water flooding following a rainfall event, resources will need to be in place for immediate implementation following an Flood Warning. Within flooded areas, actions such as the closure of roads and diversion of traffic may be required. A strategy for the safe evacuation of residents will also need to be revised based on the surface water modelling outputs contained within this document.

Permeable paving: Installing permeable paving in key risk areas and along key overland flow routes. These systems can assist in reducing the amount of runoff entering the drainage network, and assist in reducing the overall risk of flooding from an extreme rainfall event.

Rainwater harvesting and water-butts: Improving the resilience of local communities to flooding can be achieved through raising awareness of simple measures and systems that can be installed at their homes. Local residents and property owners may, for example, be encouraged to install simple systems such as water butts to capture roof runoff. Alternatively, rainwater harvesting systems could be installed in new developments or schools.

The principle of rainwater harvesting is that rainfall from roof areas is passed through a filter and stored within large underground tanks. When 'grey water' is required, it is delivered from the storage tank to toilets, washing machines and garden taps for use. Any excess water can be discharged via an overflow to a soakaway or into the local drainage network.

One of the preferred options to reduce peak discharges and downstream flood risk is the implementation of water butts on all new development within the existing urban areas, and in addition, retrofitting these to existing properties where possible.

Water butts often have limited storage capacity given that when a catchment is in flood, water butts are often full and have no spare capacity for flood waters. However, it is still considered that they have an important role to play in the sustainable use of water. There is potential to use 'leaky' water butts that provide overflow devices to soakaways or landscaped areas to ensure that there is always some volume available for storage during heavy rainfall events.

Larger rainwater harvesting systems should also be implemented within suitable developments within the Borough (e.g school facilities, commercial buildings etc)

Retrofitting bioretention/rain gardens carpark bays: retrofitting bioretention features in key risk areas and along key overland flow routes will act as a source control measure to reduce the amount of runoff entering the drainage network, and reducing the overall risk of flooding from an extreme rainfall event. These devices also can enhance the aesthetics and biodiversity of an area due to their landscaping. These devices have been found to assist in reducing the total amount of phosphorus and nitrogen that discharge into downstream waterways as a result of adsorption and absorption processes within the filter media and plant growth and die off and therefore improve the quality of the runoff discharging into the downstream network.

Hydrometric monitoring: It is recommended that installing a series of hydrometric monitoring systems across the Borough catchment would provide a stronger understanding of rainfall patterns and flows that lead to surface water flooding across King's Lynn and West Norfolk. Rain gauges and flow gauges should be installed in targeted areas so that a detailed understanding of the catchment hydrology can be established. This evidence base can be used to inform future studies and flood alleviation projects across the Borough.

Norfolk County Council should develop an integrated framework to support emergency response and flood incident management. In conjunction with this, it is recommended that rainfall gauging stations can be used to assist with this aim, as well as to assist with the Council's responsibility of investigating flood incidents as required under the FWMA 2010.

Preferential overland flowpaths (Urban Blue Corridors): Surface water can be managed through the designation of existing highways as Urban Blue Corridors. This concept aims to manage the conveyance of surface water across an area of the catchment through the redesign of the urban landscape to create specific channels to convey surface water. This can be achieved through increasing kerb heights and property thresholds to retain water on the roads. This option could be combined with existing highways maintenance and improvement projects and funding which would make it more cost-effective.

Raising community awareness: Communicating the risk of flooding and raising awareness within local communities across the Borough can be implemented in the short-term and provides a 'quick win' measure to surface water management. This will mean residents are more aware of the flood risk across modelled settlements (and wider Borough) and can encourage people to become more proactive within their community. Increasing awareness can be achieved through public consultation events, newsletters and online resources such as council websites and social media.

It is also important that modern technology is fully utilised in order to communicate with the local community as best as possible. The Environment Agency have produced an iPhone App which delivers data from their online flood warning service straight to people's phones; this is an excellent example of how innovative thinking and technology can be applied to the communication of flood risk. In the first instance, it is recommended that social media platforms such as Google+, Facebook or Twitter are utilised as a way of communicating with local residents and providing information on the council's flood and water management activities; this can be an easy 'quick win' action.

6.2 Short – Medium Term Recommendations

Accounting for the nature of the surface water flooding in the Borough, it is considered that the following actions should be prioritised in the short to medium-term:

- Determine pipe sizes for all settlements within the Borough to determine those at risk of systems which are under capacity or conveying flows from unintentional sources (open space, residential and other impervious landuses that discharge directly onto the road etc)
- Undertake a feasibility study for providing source control and flow path management measures in relevant open space areas within the Borough;
- Confirm the flood risk to all Network Rail and Highways Agency assets and agree a timeframe for the detailed assessment of areas of concern.
- Undertake a Borough wide feasibility study to determine which roads may be retrofitted to include bioretention capark pods;
- Improve maintenance regimes, and target those areas identified as having blocked gullies;
- Identify and record surface water assets as part of the LLFAs Asset Register, prioritising those areas that are known to regularly flood and are therefore likely to require maintenance / upgrading in the short-term;
- Collate and review information on Ordinary Watercourses in the Borough to gain an improved understanding of surface water flooding in the vicinity of these watercourses. This may require detailed hydraulic modelling to determine the risk posed by these watercourses;
- Provide an 'Information Portal' via Borough website, for local flood risk information and measures that can be taken by residents to mitigate surface water flooding to / around their property. This could include:

- A list of appropriate property-level flood risk resilience measures that could be installed in a property;

- A list of 'approved' suppliers for providing local services, such as repaving of driveways, installation of rainwater tanks and water butts etc;

- link to websites/information sources providing further information;

- An update on work being undertaken in the Borough by the Council and/or the Stakeholders to address surface water flood risk; and,

- A calendar showing when gullies are to be cleaned in given areas, to encourage residents to ensure that cars are not parked over gullies / access is not blocked during these times.

- Production of a Communication Plan to effectively communicate and raise awareness of surface water flood risk to different audiences using a clearly defined process for internal and external communication with stakeholders and the public.

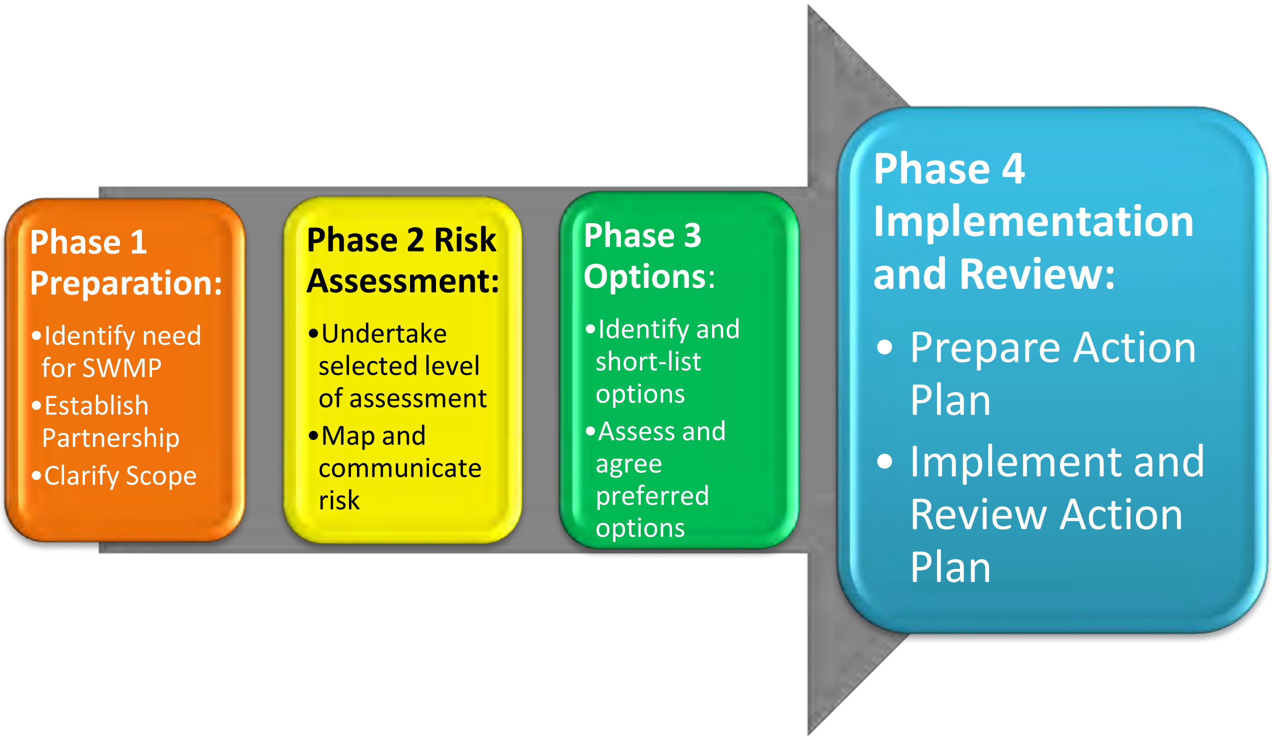
- Refine the direct rainfall hydraulic model with:

  - Detailed survey of structures that may influence the hydraulics of the catchment;

  - Integrate the drainage network within the model; and

  - Incorporate actual infiltration losses based on results of actual testing of insitu soils within the catchment.

PHASE 4: IMPLEMENTATION AND REVIEW



7 Purpose of an Action Plan

The Action Plan outlines a wide range of recommended measures that should be undertaken to manage surface water within the Borough more effectively. The Action Plan has been developed to outline the responsibilities and implications of both structural and non-structural preferred options discussed in Phase 3 of the SWMP. The Action Plan details the methods, timescale and responsibility of each proposed action.

Within the Action Plan there are details of general measures that could be implemented across the Borough. The general actions are non-structural and encourage improved surface water management through planning policy and public education and awareness. The general actions also include the development of a flood response strategy and surface water flood warning system, which would be beneficial in ensuring successful response, with minimal harmful consequences, in the event of extreme surface water flooding.

As part of the preparation of the Action Plan and the SWMP, the requirement for a Strategic Environmental Assessment (SEA), an Appropriate Assessment (required by the Habitats Directive) or an Article 4.7 assessment (under the Water Framework Directive) was considered. From a review of these areas it was identified that the Dersingham Bog is considered a Special Area of Conservation, however a 'screening decision' was made which suggested that the SWMP alone does not require any of the environmental assessments described above. However, it is possible that any actions which are taken forward will require such assessments and it is envisaged that the requirement for this will form part of feasibility studies for individual schemes. As such, a requirement for monitoring this area is included within the Action Plan to ensure detrimental impacts to the bog are identified and rectified/managed in a timely manner

Recent guidance and policy has led to the requirement for a Local Flood Risk Management Strategy (as required by the Flood and Water Management Act, 10th December 2010). Norfolk County Council (and the Borough Council) must ensure the SWMP is aligned as closely as possible to their local strategy; this Action Plan will provide the early stages of these documents and can be used to support and inform future studies.

The Action Plan should be read in conjunction with details of the preferred options included in Chapter 11. The Action Plan is included in Appendix A of this report.

7.1 Action Plan Details

This Action Plan is a simple summary spreadsheet that has been formulated by reviewing the previous phases of the SWMP in order to create a useful set of actions relating to the management and investigation of surface water flooding going forward. It is the intention that the Action Plan is a live document, maintained and regularly updated by Norfolk County Council (the LLFA) and the Borough, as actions are progressed and investigated.

New actions may be identified by the LLFA and the Borough, or may be required by changing legislation and guidance over time.

The Action Plan identifies:

- *Legislative actions* required to satisfy the FWMA 2010 and FRR requirements - (these are common to all LLFAs);
- *General flood risk management actions* to integrate outcomes and new information from this study into the practices of other NCC/Borough services and external partner organisations;

- *Policy actions* to assist NCC and the Borough manage future developments in the context of local flood risk management;
- *Maintenance actions* to prompt review of current schedules in the context of new information presented in this study;
- *General CDA actions* to be implemented across all CDAs identified within this study;
- *High priority CDA actions* that are being implemented to better understand flood risk in specific areas and proactively manage operational risks; and
- *Underpass risk assessment* actions to highlight at risk pedestrian underpasses and understand the potential risk associated with each.

8 Implementation and Review

8.1 Overview

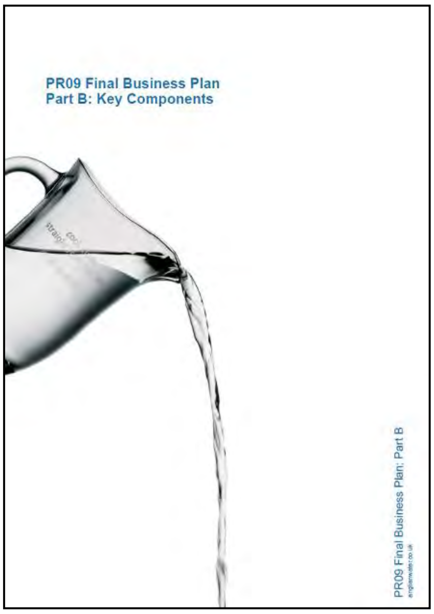
Following the completion of the SWMP, the actions detailed in the Action Plan will need to be implemented. This will require continued work within the Council and the Client Task Group to ensure all partners are involved in the implementation and ongoing maintenance and performance measures.

Norfolk County Council should coordinate with relevant internal and external partners in order to ensure a holistic approach to the implementation of outputs and actions from the SWMP. Key internal council partners include emergency planners, the highways department, planning policy and the countryside section. Key external partners include Borough Council development and regeneration services, environmental health, emergency planning and leisure and public spaces; Anglian Water, the Environment Agency and Internal Drainage Boards.

The outputs of the SWMP should be used, where appropriate, to update and adjust policies and actions. The implications of the SWMP for these partners are described below.

8.2 Anglian Water

Ofwat, the water company regulator, has also outlined their intention for water companies to work with other key partners to deliver SWMPs. In addition the Flood Risk Regulations (2009) outline a duty for water companies to provide information and co-operate with such studies. Anglian Water has been extremely helpful throughout the SWMP process and it is important that this partnership is continued into the future.



One example of how the partnership can be developed upon completion of this study is to look at how the outputs from this SWMP could be used to influence Anglian Water's investment and funding schedule for drainage improvements and maintenance programmes across the Borough. It would be extremely beneficial if their investments plans can be influenced by this study to target areas which have been identified as being at significant risk of surface water flooding due to drainage capacity issues.

Anglian Water is currently in the AMP5 period of work (set out between 2010 and 2015), and therefore it is recommended that the outputs of the SWMP should be incorporated into the next planning period (AMP6). Anglian Water's Business Plan outlines future investment strategy within the water company. The outputs and recommendations from the SWMP should feed into the decisions made about drainage and sewer flooding in key locations.

The overall aim is for the SWMP outputs to encourage a more holistic approach to future funding arrangements and schemes for drainage improvements within the Borough.

For example, the SWMP model outputs can feed into the investments plans for areas with an identified flood risk.

8.3 Spatial Planning

Implications and actions arising for Local Planning Authorities

The Defra SWMP Technical Guidance (March 2010) states that a SWMP should establish a long-term action plan to manage surface water in an area and should influence land-use planning.

PPS 25 Development and Flood Risk sets out national planning policy for development in relation to flood risk[8]. Planning Authorities have a duty to ensure that any new development does not add to the causes or sources of flood risk. PPS 25 takes a risk based approach and categorises land uses into different vulnerabilities, which are appropriate to different flood zones.

Although PPS 25 applies to all forms of flood risk, surface water, groundwater and ordinary watercourse flood risks are generally less understood than fluvial or coastal flood risk. This is due in part to the much faster response times of surface water flooding, a perception that the impacts are relatively minor and the highly variable nature of influences, e.g. storm patterns, local drainage blockages, interactions with the sewer system. In addition, until production of this report, detailed information on surface water flooding has not generally been available to local authorities.

However climate change models are predicting more frequent heavy storms and there is emerging evidence that this is already happening. It is also clear from the flooding that occurred in several parts of England in the summer of 2007 that surface water flooding can have major impacts. The detailed modelling and historical research that has been undertaken to prepare this SWMP has identified that in some parts of the modelled settlements, the risks are significant and it is important that appropriate consideration is given to these risks when new development is proposed. The planning system is a key tool in reducing flood risk and with this new and more accurate information; this can be applied to surface water flood risk as well as fluvial and tidal flood risk.

The interrelationship between SWMPs and planning was highlighted by Recommendation 18 of the Pitt Review (Cabinet Office, 2008) which states that SWMPs should:

"*build on Strategic Flood Risk Assessments (SFRAs) and provide the vehicle for local organisations to develop a shared understanding of local flood risk, including setting out priorities for action, maintenance needs and links into local development frameworks and emergency plans".*

[8] PPS 25 may be replaced by the National Planning Policy Framework once it has been adopted.

The following section identifies important implications for land use planning arising from the findings of the detailed SWMP modelling. It recommends actions for implementing the Surface Water Management Action Plan that fall within the responsibility of the statutory local planning authorities, i.e. those are responsible for the development and implementation of land use and spatial planning policy.

There are three key avenues by which the findings of this Surface Water Management Plan (SWMP) are recommended to be taken forward through the planning system:

1. The SWMP maps which identify potential areas that are more vulnerable to surface water flooding should be used to update information in SFRAs;
2. The SWMP maps which identify potential areas that are more vulnerable to surface water flooding should be used to update/prepare policies in Development Plan Documents (Development Management or Sites Allocations DPDs); and
3. The SWMP maps which identify potential areas that are more vulnerable to surface water flooding should be used to inform development decisions for sites or areas by either:
    - Resulting in modifications to strategies, guidance, or policies for major development locations (e.g. through Area Action Plans and Supplementary Planning Guidance); or
    - Influencing planning decisions in relation to the principle, layout or design of particular development proposals.

Using the SWMP to update SFRAs

Defra's SWMP guidance (March 2010) suggests that local authority planning departments use the map outputs from a SWMP to help update SFRAs where surface water flooding has not been addressed in detail. In accordance with the Defra guidance, it has been identified that the existing SFRAs do not address flooding from surface water, groundwater or ordinary watercourses in any detail.

The mapping within this SWMP shows some areas that are vulnerable to extensive deep accumulations of water (>0.5m). These areas have a high certainty of flooding during extreme storms and the damage occurring is likely to be significant. The mapping also shows some small areas of potentially deep accumulations of water (>0.5m). These areas may have particular risks associated with them, but may also occur due to irregularities in mapping and modelling. Even relatively shallow water flowing at high velocities can be a threat to life and can cause damage.

For the Borough, the production of this SWMP will be a significant addition of new/updated data. Therefore, in due course, this new information should trigger a review of the Level 1 SFRA. The SFRAs should consider these newly identified risks in the following ways:

- Large areas of deep (>0.5m) flooding should be shown as Local Flood Risk Zones, unless there is evidence to suggest that the risk has been mitigated, for example by high capacity drainage or pumping infrastructure.
- Small, isolated areas of deep (>0.5m) flooding should be investigated to determine how likely they are to be at flood risk, but do not need to be shown if there is no significant risk.
- Large areas of shallower flooding should be identified as Local Flood Risk Zones if they pose a significant risk, but do not need to be shown if the risks are relatively minor.

- Smaller isolated areas of shallower flooding should generally not be identified as Local Flood Risk Zones, unless there is a particular significant risk associated with that area, as it must be expected that most areas will be affected to some extent by rainwater.
- Routes of fast flowing water may be considered as Local Flood Risk Zones if they pose a significant risk.
- Areas of Increased Potential for Elevated Groundwater should be shown where they are likely to pose a significant risk of flooding or where they are likely to affect the nature of future development, especially for the design and use of sub-surface spaces.

Identifying an area as a Local Flood Risk Zone, should mean that it is then treated in a similar way to Environment Agency Flood Zone 3, is that development proposals will require a Flood Risk Assessment which demonstrates that measures have been implemented to reduce the likelihood and impact of any flooding.

Where a Critical Drainage Area (if identified by future studies) contributes significant amounts of surface water to a Local Flood Risk Zone, the SFRA should identify this and suggest strict application of sustainable drainage measures in this area.

Mapping Checklist

The table below indicates the SWMP maps which are of potential use to spatial planning, and indicates which maps may be suitable for replacing existing SFRA maps:

Table 8-1: SWMP maps which are of potential use to spatial planners

Issue	SWMP map reference	Consider replacing existing SFRA maps?
Surface water flood risk	Figures 9 to 14 (Appendix C)	Yes – more detailed methodology to that used for the SFRA.
Susceptibility to Groundwater Flooding	Figure 4 (Appendix C)	Yes – more detailed methodology to that used for the SFRA.
Recorded incidents of flooding	Figure D (Appendix C)	May include more recent records.

Using the SWMP to update/modify policies in Development Plan Documents

Ideally the review and update of the SFRAs should be a pre-cursor to any significant change to local Development Plan Documents. Therefore, reference to the SFRA within any local Development Plan Documents should automatically update the approach to local flood risks. Where authorities choose not to update the SFRA, any review of Development Plan Documents should consider the same steps outlined in Table 8-1 for the SFRA review.

Where Development Plan Documents (e.g. those covering site allocations and development management policies) are yet to be adopted, there is an opportunity to influence both policies and those sites which are being put forward for development.

Whether or not a review of the SFRAs is undertaken, the production of the SWMP should act as a catalyst for a review of the proposed sites being put forward through the Sites Allocations Development Plan Documents which are being prepared for the Borough. Identification of areas of Local Flood Risk which have similar levels of hazard significance as the areas identified by the Environmental Agency as Flood Zone 3 should be reflected in the site selection and screening process.

Using the SWMP to influence areas of major growth and development

The SWMP should inform consideration of how proposed new development will drain to areas of existing surface water flood risk, and therefore the runoff requirements from those development sites.

The LDF has identified a number of areas of 'Major Housing Growth and Associated Facilities' and 'Strategic Employment Sites' where significant growth is proposed.

Where major development proposals are brought forward within the King's Lynn and West Norfolk Policy Area these should be examined for:

- Local Flood Risk Zones that affect the area;
- Increased Potential for Elevated Groundwater;
- Contribution of run-off to Local Flood Risk Zones beyond the actual redevelopment area.

Local flood risk should not necessarily prevent development from taking place, but it may affect the location, uses, design and resilience of the proposals. Therefore, a Flood Risk Assessment should be undertaken to consider:

- the location of different types of land use within the site(s);
- application of the sequential approach to development layout and design;
- the layout and design of buildings and spaces to take account of flood risk, for example by dedicating particular flow routes or flood storage areas;
- measures to reduce the impact of any flood, through flood resistance /resilience measures/materials;
- incorporating sustainable drainage and rainwater storage to reduce run-off to adjacent areas; and
- linkages or joint approaches for groups of sites, possibly including those in surrounding areas.

These requirements can be set out in Development Management policies or as site specific policies in the Site Allocations DPD.

Using the SWMP to influence specific development proposals

Where development is proposed in an area covered wholly or partially by a Local Flood Risk Zone, this should trigger a Flood Risk Assessment, as already required under PPS25.

Whilst some small scale developments may not be appropriate in high risk areas, in most cases it will be a matter of ensuring that the Flood Risk Assessment considers those items listed above and also considers some or all of the following site specific issues:

- Are the flow paths and areas of ponding correct, and will these be altered by the proposed development?

- Has the site been planned sequentially to keep major surface water flow paths clear?
- Has exceedance of the site's drainage capacity been adequately dealt with? Where will exceedance flows run off the site?
- Could there be benefits to existing properties at risk downstream of the site if additional storage could be provided on the site?
- In the event of surface water flooding to the site, have safe access to / egress from the site been adequately considered?
- Have the site levels been altered, or will they be altered during development? Consider how this will impact surface water flood risk on the site and to adjacent areas.
- Have inter-dependencies between utilities and the development been considered? (for example, the electricity supply for building lifts or water pumps)

8.4 Emergency Planning

Presently, surface water flooding is not as clearly understood as other sources of flooding (such as fluvial or coastal). Therefore, this SWMP study offers an opportunity to communicate up to date information about locations at risk from surface water flooding to those with an interest. Emergency responses will be informed by known surface water flooding locations, especially near public buildings and major routes through the area.

The purpose of this section is to assist in communicating surface water flood risk to Local Resilience Forums and Emergency Planners to enable them to ensure that incident management plans are updated based on the improved understanding of surface water flooding.

The Norfolk Resilience Forum (NRF) has a variety of emergency response and recovery plans for both specific and general major incident risks. The need for specific plans is identified through the Community Risk Register. The key overarching plan for Norfolk is the Norfolk Emergency Response and Recovery Strategy (NERRS) which sets out how the agencies involved with the response and recovery to major incidents will work together (the NERRS is a public document and is available at www.norfolkprepared.gov.uk). In relation to flooding the NRF has a Strategic Flood Plan which deals with the overall County wide response to flooding and a Tactical Flood Plan which looks at the district level response; some community level plans have also been produced and work is ongoing to increase the number being developed. For a wider range of weather related hazards the NRF has developed a Strategic Severe Weather Plan. Because an important aspect of any incident is the need to warn and inform the public the NRF has produced the Norfolk Emergency Media Plan which details how the NRF will work with the media in providing timely and accurate information in the event of an emergency. Regular training and exercising of these and other multi-agency NRF plans is carried out to ensure that Norfolk is able to respond effectively to major incidents.

SWMP mapping outputs and knowledge should be used to inform emergency planning decisions and ensure emergency responses to surface water flood events can be improved through identification of likely flow paths and locations of surface water ponding. In particular the following documents should be reviewed and updated following the understanding gained from the SWMP:

- Community Risk Registers (CRR); and
- Multi-Agency Flood Plan (MAFP).

Community Risk Registers (CRR) are prepared by Category 1 responders and are required as part of the Civil Contingencies Act (CCA) 2004. The CCA requires that Category 1 responders undertake risk assessments and maintain these risks in a CRR. In this context risks are defined as events which could result in major consequences, and they include risks from flooding.

However, to date the majority of CRRs do not include surface water flood risks, and outputs from the SWMP can be used to help update the CRR. In particular, the SWMP presents the opportunity to identify and engage with as many vulnerable receptors as possible. This may include individual households as well as organisations or groups.

Multi-Agency Flood Plans (MAFP) are specific emergency plans which should be developed by LRFs to deliver a coordinated plan to respond to flood incidents. MAFPs recognise the need for specific flooding emergency plans, due to the complex nature of flooding and the consequences that arise and are developed to enable the diverse range of organisations involved during a flood to work together effectively and manage the consequences of flooding.

Outputs from SWMPs should inform the development of, or update, the MAFP. The SWMP mapping should be used as an initial indicator of possible risk. A Flood Risk Assessment at a site shown as being at risk of surface water flooding should consider:

- Impacts on receptor sites;
- The degree of receptor vulnerability; and
- In the event of surface water flooding to the site, has safe access to and evacuation from the site been adequately considered?

Within Norfolk County Council, emergency planning is conducted by the Resilience Team. The Resilience Team works with the Norfolk Resilience Forum (NRF) in coordinating planning, training, exercising and the activation of plans; it works alongside the Emergency Services, neighbouring councils and other agencies in the response and recovery to incidents such as flooding. When required the Resilience Team can provide support to King's Lynn and West Norfolk Emergency Planning or may take the lead in large scale incidents. The SWMP recognises the need to review the planning for flood events due to the complex nature of flooding and the consequences that arise from extreme surface water flooding. The outputs from this SWMP will therefore provide valuable information on surface water flood risk across the modelled settlements.

The MAFP should be continually revised to incorporate new knowledge or information. The SWMP modelling outputs should be used to inform and update the MAFP, as the SWMP maps highlight areas at risk of surface water flooding and areas where there is a high hazard associated with surface water flooding. This information should be used to develop specific plans that focus on areas at high risk within the modelled settlements. This will ensure that resources are focussed in relevant areas in the event of flooding. The maps and figures included in Appendix A detail the flood depths and flood hazards modelled across the modelled settlements.

The **Flood Guidance Statement** (FGS) provides information for Category 1 and 2 responders to help them with their emergency planning and resourcing decisions. It presents an overview of the flood risk for England and Wales across five days and identifies possible severe weather, which could cause flooding and significant disruption to normal life. The FGS incorporates the **Extreme Rainfall Alert (ERA) service** which was set up by the Met Office and the Environment Agency (as part of the Flood Forecasting Centre) in 2008 in order to provide services to emergency and professional partners. The FGS assesses the risk for all types of natural flooding – river, coastal, groundwater and surface water flooding.

Surface water flooding has very short lead times and is hard to predict in real time because local topography and drainage infrastructure affect the direction of runoff and location of flooding. However, the mapped outputs from the SWMP provide valuable information on likely flow paths and key ponding areas that are likely to flood as a result of land use and topography. This will allow emergency services to focus their resources on areas that have been identified as being at high risk of surface water flooding.

Key actions for emergency planners in response to the SWMP include:

- Review Multi Agency Flood Plans using the SWMP mapped outputs to focus emergency response actions on vulnerable areas with the greatest risk from flooding;
- Utilise the FGS for flood forecast alerts and implement this into the Council's Multi Agency Flood Plan;
- Use the flood hazard outputs to evaluate safe access and evacuation routes to and from flooded areas;
- Use model outputs to determine areas where specific emergency flood plans should be developed (i.e., particular vulnerable communities or specific CDAs);
- Increase education and awareness in communities at risk of surface water flooding;
- Create a key facts and 'what to do' section for surface water flooding in emergency handbooks; and
- Work with other agencies (such as the Environment Agency flood alert schemes) in the interests of cost effectiveness and good communication.

It is important that these actions are carried out in conjunction with the Borough emergency planners, who have overall responsibility for emergency planning in their areas.

8.5 Highways

The highways department within Norfolk County Council, as the highways authority, is responsible for managing and maintaining the road drainage network within the Borough. It has a variety of responsibilities ranging from repairing potholes to salting the roads during cold and icy weather. It is also responsible for ensuring that drains and gullies are kept clear from debris such as soil, dead leaves and rubbish.

This type of debris often builds up in drains preventing the flow of water into the surface water or combined sewers and requires frequent maintenance. If drains become blocked during a heavy rainfall event it can exacerbate the severity of flooding that occurs locally.

The Council's highways department is identified as one of the key partners in this SWMP study and its involvement and engagement in the process has been actively encouraged. It is important that the outputs from this SWMP are used effectively in order to support and inform the future management practices of the Borough's road infrastructure. In particular, consideration should be given to the key recommendations which are discussed in the following section.

The main recommendations and actions that the highways department should take from the SWMP process include the following key points:

- The existing schedule of drain and gully maintenance is recommended to be re-evaluated in order to give particular attention to areas considered to be at the highest risk of surface water flooding. This should be undertaken for all settlements within the Borough. Drains and gullies in these areas should be kept clear throughout the year to maximise the capacity of the drainage network and reduce the risk of blockages; this should be reflected in the highways maintenance schedule.

- Opportunities for joint funding on improvement work within the Borough should be considered. Highway maintenance and improvement projects could be combined with drainage improvement or flood alleviation projects through a more holistic approach within the council. For example, highways drainage programmes may offer opportunities to incorporate useful changes to overland flow paths or increase drainage capacity within a surface water flood risk hot spot with little extra cost. This would provide a time and cost effective way to manage the resources of the council and ensure different departments are involved in working together to reduce the flood risk across the Borough.

8.6 Review Timeframe and Responsibilities

Proposed actions have been classified into the following categories:

- Short term: Actions to be undertaken within the next year.
- Medium term: Actions to be undertaken within the next one to five years.
- Long term: Actions to be undertaken beyond five years.

The Action Plan identifies the relevant internal departments and external partnerships that should be consulted and asked to participate when addressing an action. After an action has been addressed, it is recommended that the department responsible for completing the action should review the Action Plan and update it to reflect any issues (communication or stakeholder participation) which arose during the completion of an action and whether or not additional actions are required.

It is recommended that the Action Plan is regularly reviewed and updated to reflect any necessary amendments. In order to capture the works undertaken by the NCC and Borough and other stakeholders, it is recommended that the Action Plan review should be on a not greater than annual basis.

For clarity, it is noted that the FWMA 2010 places immediate or in some cases imminent new responsibilities on LLFAs. The main actions required are summarised below:

- Develop, maintain, apply and monitor a Strategy for local flood risk management of the area.
- Duty to maintain a local flood risk asset register.
- Investigate flood incidents and record in a consistent manner.
- Establish a SuDS Approval Body (SAB).
- Contribute towards achievement of sustainable development.
- On-going responsibility to co-operate with other authorities through sharing of data and expertise.
- Preparation of Local Flood Risk Management Strategies

8.7 Ongoing Monitoring

It is intended that the partnership arrangements established as part of the SWMP process, will continue beyond the completion of the SWMP in order to discuss the implementation of the proposed actions, review opportunities for operational efficiency and to review any legislative changes.

The SWMP Action Plan should be reviewed and updated annually as a minimum, but there may be circumstances which might trigger a review and/or an update of the Action Plan in the interim. In fact, Action Plan updates may be as frequent as every few months. Examples of something which would be likely to trigger an Action Plan review include:

- Occurrence of a surface water flood event;
- Additional data or modelling becoming available, **which may alter the understanding of risk within the study area**;
- Outcome of investment decisions by partners is different to the preferred option, which may require a revision to the action plan, and;
- Additional (**major**) development or other changes in the catchment which may affect the surface water flood risk.

It is in the interest of Borough and the residents of the catchment, that the SWMP Action Plan remains current and up-to-date. To help facilitate this, the Borough and NCC will liaise with other flood risk management authorities and monitor progress.

8.8 Incorporating new datasets

The following tasks should be undertaken when including new datasets in the SWMP:

- Identify new dataset;
- Save new dataset/information; and
- Record new information in log so that next update can review this information.

8.9 Updating SWMP Reports and Figures

In recognition that the SWMP will be updated in the future, the report has been structured in chapters according to the SWMP guidance provided by Defra. By structuring the report in this way, it is possible to undertake further analyses on a particular source of flooding and only have to supersede the relevant chapter, whilst keeping the remaining chapters unaffected.

In keeping with this principle, the following tasks should be undertaken when updating SWMP reports and figures:

- Undertake further analyses as required after SWMP review;
- Document all new technical analyses by rewriting and replacing relevant chapter(s) and appendices;
- Amend and replace relevant SWMP Maps; and
- Reissue to departments within the NCC, BCKLWN and other stakeholders.

9 References

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